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# TELECOMMUNICATIONS

## Germany: Information Technology Subsidy Program 1993-1996

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[Text]

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**Preface**

In addition to institutional research funding in the area of project support, the Information Technology subsidy concept fulfills the research policy framework established in 1989 by the Federal Government's Information Technology plan for the future. Within the overall perspectives for funding information technology in the FRG, this subsidy concept includes research and development in telecommunications technology as well as support for information technology through EC programs and TELEKOM. Corresponding programs already exist for the areas of work and technology, as well as production technology and quality assurance; measures for the field of technologies of the 21st Century are being prepared.

In recent times information technology has continued to expand its key role as a motor for technical and industrial progress. Furthermore, like no other technical development it also opens up multiple chances and opportunities for intelligent resources and energy-saving products in all areas of life. Information technology thus represents a particular challenge for government research and technology policy. Government research support in the FRG has as its goal to assure a strong scientific and technical research infrastructure and to support the transfer of the results of the basic research to industrial application. With this objective, the Federal Research Ministry concentrates more than a third of its funding in the field of institutional support; two-thirds of the funding goes, within the framework of project support, in approximately equal parts to government research institutions and research and development in companies. The establishment of research institutions in the new laender offers a special opportunity but also demands additional efforts. Here, new, highly qualified partners for contact and cooperation are emerging for the information and communications technology industry. The Society for Mathematics and Data Processing (GMD), being a major research institution in information technology, is in the process of reorganizing its theme and organization and has taken into account the rapid changes in the demand for future topics in a dynamic process of institutional renewal. This support for the research infrastructure is competition-neutral and contributes decisively to the fact that Germany, thanks to its scientific attractiveness, remains a preferred location for industry. The laender participate in this task by means of education at academic institutions, institutes of technology and other schools in the field of information technology, thus also sharing in the research.

In the pre-competitive area the main focus of the research funding is aimed at cooperation between the economic sector and science in the form of joint projects and the transfer of know-how and, to an equal extent, with the development and implementation of norms and standards for opening up markets. In the market sector there are worldwide efforts to remove trade barriers of all kinds, and new EC barriers must be avoided. The collapse of the public-economic systems in Eastern Europe has once again showed that technical and social progress are best achieved with a market-economic system. Monitoring the competition through observation and sanctions against violations is an important precondition for effective research support.

At the European level the focus of the research policy lies in supporting research cooperation across the borders and in tackling new technical visions in various walks of life. It will be crucial for the success of European cooperation not only to increase the funding but early on to recognize the public and private need for problem solutions through information technology and quickly convert them with imagination and market savvy into new products. In the year 1992 about 280 million German marks [DM] in funding will flow from the EC to the FRG. Over the next five years this amount will double. In view of the key role of the information and communications technology for the competitiveness of the economy, the BMFT has produced a 10-point memorandum on the research support of the European Community in the field of information and communications technology and submitted it to the EC Commission. The memorandum stresses the importance of the European research policy as a measure to supplement national research and technology policies, and it urges strategic concentrations for European subsidies, easier access for small and medium-sized companies and that on the level before standards are established R&D should be oriented toward the standardization initiatives on the world market. Together with the German information and communications technology industry, with which the BMFT carries out a continuous dialog, it influences the EC's program discussions toward these objectives.

The success of all government measures depends on initiatives by industry, science and research themselves. This subsidy concept offers incentives and financial support measures, within the framework of which these self-initiatives can develop. The rapid progress in the research and development of information technology should receive additional impulses from it; over the period of this subsidy concept it will also lead to changes which require quick reactions by the research policy: This subsidy concept is therefore a part of the change which it helps bring about.

Dr. Heinz Riesenhuber Federal Minister for Research and Technology

**1. Importance of Information Technology**

Information technology plays a key role in the economic and social development of modern industrial nations. Like no other technical development it leaves its mark on our age and has become the most important dynamic factor in the modern industrial society. Information technology opens up opportunities for technical progress, it contributes to the improvement of people's ecological and social living conditions. At the same time it is an important factor in the competitiveness of the economy.

The overwhelming importance of information technology is based on the fact that on it supplies tools to support intelligent handling and behavior on favorable conditions. In so doing, it reinforces a significant human ability not only to absorb information, to store it and to reflect on it, but actively to use it to create material and immaterial goods. The systems, installations and methods of information technology have therefore acquired the function of general performance enhancers, and they increasingly represent the joint, technical nerve system of the economy and government. Finally, information technology changes the shape of work and leisure time, the form of public communication and control, the

way people live together, the development of the individual and of society and the forms of interpersonal relations, and it ranges all the way to the continued development of culture. In all these areas permanent impact has taken place and may be expected again through information technology and its applications.

The concept of information technology includes all the branches of the electronics industry, both applications and services:

- Microelectronics
- Information science
- Communications technology
- Software
- Office technology
- Industrial electronics/microsystem technology
- Consumer electronics

The world market volume in information technology was a total of 737 billion dollars in 1989, with an above average rate of increase of about 10 percent a year. If communications technology services are included, the information technology sector recorded sales of DM 1.4 billion in the year 1990.

A recent OECD estimate arrives at the conclusion that the share of information and communications technology products and services of the gross social product of the industrial societies will double by the end of the decade. In the European Community sales of information and communications technology in 1990 were DM 350 billion, which is the equivalent of about four percent of the gross social product of the Community. This share is expected to grow to 10 percent in the year 2000. To this is added the special nature of information technology as a multiplier for technical and economic progress. Even today, two-thirds of all jobs are directly or indirectly affected by information technology.

The emphasized strategic importance of information technology consists of the fact that on a broad basis it generates interdisciplinary effects for many other areas of the economy, in particular for small and medium-sized enterprises. These send out important impulses for structural changes in the entire economy. In the FRG information technology decisively influences an area of the heavily exporting investment goods industries that is seven to eight times larger, that is to say for every DM 1 in sales by the information technology industry, DM 7 to 8 in influenced sales benefit the five largest exporting German investment goods industries.

A notable highlight of the importance of information technology is provided by an analysis published in 1990 by the U.S. Department of Commerce on the global competitive situation in the United States compared with Japan and Europe for the most promising future technologies. Of the 12 future technologies mentioned, no fewer than eight could be classed in the field of information technology.

The importance of information technology goes far beyond its key economic role. Hardly any other technical development right now leads to such radical structural changes in all walks of life as information technology. It is the source of innovations in the economic and cultural area, and it provides crucial instruments for environmental protection and economic use of resources by means of electronic measurement and control systems as well as data bases and information-processing systems.

Information technology and its increasing application in the production and service sectors has a significant influence on the working environment. It creates, changes and replaces jobs. Manufacturers and suppliers create jobs; when productivity grows from using information-technical solutions, opportunities for creating new jobs open up for the users, jobs change and opportunities follow to make the labor organization, job structure and job contents more suitable for human beings. The META studies funded by the BMFT have shown that the net result of information technology will be positive effects on the development of the labor market and the number of jobs. Recently reported studies on the effects of information technology on the European labor market have yielded similar results.

Information technology results in a new type of interlinking of social and technical infrastructures. Its effects equally influence the workplace and private life.

Information technology thus represents a special challenge for government research policy. Because of the far-ranging impact of information technology on a whole range of other policy fields such as industrial and technology policy, educational policy and telecommunications policy, research policy must not be regarded as isolated; the numerous lateral connections between these policy areas must be taken into account. For this reason the Federal Government decided in 1989 to present its policy in the area of information and communications technology in a future-oriented concept on a supradepartmental level.

The Information Technology Future Concept establishes a program framework which encompasses the government's measures to promote the development and application of information technology in various fields of policy on a supradepartmental level.

Being a framework concept, the future concept itself can thus only hint at the numerous measures. The various departments involved in the future concept are therefore charged, each in its own field, with filling in the program framework outlined by the future concept with their own action programs.

The BMFT's present subsidy concept is being brought out at a time of rapid technical progress and considerable structural changes. The importance of applications-oriented basic research in information technology is being reevaluated and redefined worldwide; both in the United States and in Japan greater efforts have been initiated based on the results of scientific discussions.

International industrial cooperation is making rapid progress and leads to new groupings. Only as strong partners do German science and the German economy stand a chance of playing a commensurate role in the increasing international competition within Europe and globally.

The objective of the subsidy concept is to maintain and expand the FRG as an attractive location for research, development and production of information and communications-technical production and to support the positions of German science as well as German industry as strong partners in the international competition. Existing strengths in research and development are to be expanded, insofar as the economy recognizes them as promising and important. The integration of information technology with other sciences such as biology, environmental and climate research or transportation research, is promoted through institutional funding for basic research in government research institutions as well as through support of projects in science and industry. All of these efforts can only unfold their full effectiveness in a public environment of technology acceptance and understanding of the social benefits of shaping the technology. Science, economy and state here face a common challenge.

The present subsidy concept describes the measures which the BMFT plans to use in promoting research and development in the field of information technology. When basic research is mentioned here, it is, in agreement with the recommendations of the Commission for Basic Research of the Federal Minister for Research and Technology, understood to be the development of a course of knowledge for technological, industrial and cultural development, from which come solutions to urgent questions and tasks in society and for intellectual life. Basic research therefore means neither isolated discipline-related scientific efforts nor scientific studies in the ivory tower insulated against the problems and challenges of our society. On the contrary; it includes a broad spectrum of searching for new knowledge, deeper understanding and proposals for solutions to sets of questions which come from science itself, from industry or from social need. Depending on the problem and the scientific field, it therefore often extends all the way to practical implementation in products and methods, without, to be sure, overstepping this threshold. Since it must remain creative, basic research is to be kept free of the shackles of time restraints from the institutional research support of the Federal Government and laender. In normal instances it offers various options to be selected for utilization by the economy; however, quality and originality usually determine the opportunities for practical application and implementation, as well as the funding within the framework of BMFT research projects.

Research and development play a particularly important role in information technology, since the enormous development pace needs major efforts in strengthening the national research infrastructure and requires especially large research and development investments in the information technology and consumer industry. The research intensity in this sector can be illustrated by the fact that about one-fourth of the total worldwide spending on research and development can be attributed to the field of information technology.

It turns out that in the FRG and Europe, despite greater allocations by companies for R&D and despite reinforced government research subsidies on the national and European levels, it has not been possible to reduce to the desired extent any weaknesses that have occurred in the past in industrial production and application of information-technological goods. This applies to the field of microelectronics and computer technology in Europe and in the FRG also the field of software production, whose share of the information and communications technology systems is showing an increasing trend.

A strong research infrastructure and government support for R&D involvement are important preconditions for the international competitiveness of research-intensive industries, to be sure, but government R&D programs can—by themselves—not guarantee industrial competitiveness. For that reason a continued development of the prerequisites is needed so that the innovative capability of the companies—particularly in medium-sized and small ones—will be strengthened and placed in a better position to produce and use modern information technologies in ways suitable to the market and competitively. But government subsidies cannot replace the important efforts of the information technology and user industry itself.

In Europe more and more voices have recently been raised which, in addition to research policy, call for supplementary industrial and technology policy measures to improve the dynamic of innovations ("Report of the Commission of the European Communities of 3 April 1991: The European Electronics and Information Technology Industry—Situations, Opportunities and Risks, Proposals for Action").

The Federal Government stated its position on these proposals in the decision by the Council of the EC Ministers of Industry on electronics, information science, and communications technology of 18 November 1991. The orientation toward the global market must apply to information technology as well. Restrictive trade policy measures to protect the domestic market are rejected. In the future it is therefore important to open up European cooperation to enterprises outside Europe, whereby efforts are to be made to achieve mutual benefit and balance; to support the establishment of production sites in Europe by companies with a capital majority outside Europe, in which the link to corresponding R&D in Europe appears particularly important; to assure worldwide, open competition in the field of information technology and to prevent market-dominating monopolies.

The rapid change caused by information technology in science, economy, and society also means constantly new requirements for research policy. The present subsidy concept must remain open to such changes in order to be able to open up new options for scientific and technical progress. It is thus understood as an offer to science and technology that it will keep up with international demands in the innovative process of information technology.

**2. Goals and Functions of Government Research and Technology Funding for Information Technology**

**2.1 National Tasks**

The overriding goal of government research and technology policy lies in keeping Germany attractive as a research location and expanding this function for companies in the field of information technology.

One crucial prerequisite for being an attractive site for high-tech industry is well trained professional labor. This is one of the indisputable strengths of the FRG. That is why the research policy is also aimed at finding information-technical solutions in the production and service sector with which the existing expertise can be utilized and further developed and in which through new forms of work organization, made possible by the progress in information technology, the creativity and motivation of the skilled labor is reinforced and the experienced knowledge of the professional workforce becomes part of the information technology.

Of equally great importance is a favorable innovation climate, which originates from a strong research infrastructure. The BMFT's funding measures are therefore directed toward strengthening application-oriented basic research in the field of information technology and accelerating the transfer of research results to practical industrial application.

In the Fraunhofer Society, the Max Planck Society, academic institutions, major research facilities and Blue List installations the FRG possesses outstanding institutional preconditions. The spectrum of tasks and the goals of these establishments are set out in detail in the future concept. The future prospects for information technology in the Max Planck and Fraunhofer Societies, at large research establishments (GMD, KfA [Juelich Nuclear Research Facility], KfK [Karlsruhe Nuclear Research Center]) as well as at the Blue List institutes—including the research concentrations at newly founded institutes in the new laender—are given in the supplement.

This research supplies the foundation for the innovations of tomorrow, but this innovation can only take place through a functioning technology transfer. That is why the BMFT's subsidy measures put priority on including every conceivable transfer mechanism in an intensive way. For example, the academic institutions of the FRG are indispensable for the transfer of technology, because they send out highly qualified graduates who make use of their innovative knowledge from research projects in their professional work. Particularly small and medium-sized enterprises obtain their innovative strength largely from this "technology transfer by means of heads." Above all, in order to assure this type of technology transfer, it is the declared goal of the BMFT to integrate the academic institutions closely into the research support.

With the concept of scientific infrastructure in this subsidy concept is meant broad understanding of institutionally assured research at universities, government research establishments outside universities and in the economy. As is also shown in international comparisons, a balanced relationship between these three areas, as well as the measure of their mutual transparency and collaboration, competition that strengthens performance and the personnel exchange connected with it, represent essential prerequisites for success and quality of results. Structural rigidities in the field of scientific infrastructure, mutual isolation or sterile parallel existence hinder or delay new developments and extraordinary results. By support of the scientific infrastructure in this subsidy concept is also meant regular understanding of the effort to make the structures themselves vital, flexible, and mutually fruitful.

In a rapidly developing sector such as information technology, it is important in international competition to push the conversion of research results into industrial application. The BMFT's support measures in the field of application-oriented basic research are therefore predominantly organized in the form of joint projects between science and industry. The industrial enterprises share in the R&D spending and both groups participate by sharing the work in the interest of the goals defined by the industrial partners. In this manner synergies are mobilized in cooperation between research groups with government financing, using engineers from industry to the advantage of both groups. Furthermore, it is precisely the close cooperation between science and industry on joint projects which produces new, interesting questions for basic research. Also, the supply of competent next-generation scientists is enlarged, who at an early stage have learned the efforts required to convert scientific results into industrial application. That is an experience which facilitates the transfer to industry and, hence, the technology transfer inside people's heads. Efficient project management, such as through project sponsorship arrangements, and effective methods for monitoring success, raises the degree of impact of the subsidy measures.

The considerable R&D efforts of the industry in the field of information technology—they are about seven times greater than the government funding—are shown in the following statistical breakdown; they form the basis for the supplementary government funding.

| Industry Spending for Information Technology R&D (million DM) | | | | |
|---|---|---|---|---|
| 1983 | 1985 | 1987 | 1989 | 1991 (est.) |
| 5,390 | 6,930 | 8,050 | 8,540 | 9,500 |

Source: SV Wissenschaftsstatistik GmbH, (calculation basis: 70 percent of the electrical engineering sector)

Also disproportionately greater is the advance work in R&D demanded from the users of information and communications technology components.

**2.2 European Tasks**

The national research infrastructure and the companies' own R&D involvement are important cornerstones for the European research and technology community. The European ESPRIT and RACE subsidy programs in the field of information technology are aimed at increased cooperation by scientists and engineers across national borders and at creating the technological foundations for a European information technology industry that can keep up with the global competition of the 1990's. The impulses generated by an innovative national research environment play an important role in this creative process on the European level.

In the preliminary program phase on the community level promising topics must be picked up early and the results brought into the European discussion. That way national basic and application-oriented pioneering research can share in shaping the goals and tasks for the research programs of the European communities. The quality of the European programs depends decisively on the stimuli originating from national research contributions. Besides, the expertise gained within the framework of groundlaying national work makes the participants interesting partners for European cooperation and establishes the preconditions for successful participation in European programs. That is why national and European research efforts are mutually dependent and supplement each other.

The EC's R&D programs must also provide a contribution to the strengthening of the economic and social contents of the community and to promote their harmonious joint development ("cohesion goal"). In so doing, the scientific and technical quality of proposals must always be taken into account; in practice, however, this conflicts with the interests of member nations with lower standards of technology, primarily as regards the overriding strategic importance of information technology for European competitiveness in the global competition with the United States and Japan. In its 10-point memorandum on research support by the European Communities in the field of information and communications technology the BMFT has demanded political solutions at the Community level. A proposal for a solution introduced by the BMFT in the most recent debates on a Fourth R&D Framework Program could involve opening up and utilizing the specially appropriated EC funds for regional and structural policy more heavily for R&D projects and for establishing the scientific and technical infrastructure.

Another task for the national research policy consists in supporting the EUREKA initiative. EUREKA offers a supplementary incentive to the European communities' funding programs that have a broad subject approach. While community programs are intended to strengthen European cohesion, which sometimes also leads to technologically less developed regions or industries merely being elevated to the level of the more highly developed ones, in EUREKA the participants from the beginning deliberately establish strategic concentrations on a narrowly defined, joint objective. Examples in the field of information technology are the creation of a system for high-definition television (HDTV), the initiatives for expanding the European system of know-how in the field of microelectronics (JESSI [Joint European Submicron Silicon Project]) and the EUREKA software factory (ESF). These strategic projects are based on cooperation between a few, particularly strong European firms and top teams in basic research.

With respect to European cooperation, the overall system of government support for information technology essentially consists of the three elements described:

- National basic research to acquire preliminary knowledge,
- European research support through the European Communities to strengthen international competitiveness (Europe as a high-tech location),
- EUREKA initiatives for concentrated use of resources by interested, equal partners on strategic objectives.

Each of these three elements fulfills its specific role for the entire system of R&D. It is the task of the research policy to furnish a lively and fruitful exchange of the individual elements. This also includes special measures to integrate the new laender.

The BMFT subsidy measures are embedded in the following overall Federal Government strategy within the framework of the Information Technology Future Concept:

- Priority is given to strengthening the scientific and technical infrastructure of the FRG in the field of information technology; one-third of the research funding is concentrated to institutional research. This funding is competitive-neutral—the FRG must remain a preferred industrial location thanks to its scientific attraction.

- In the pre-competitive area the focal point of the support is on cooperation between science and the economy. Further, there is implementation of new standards and norms through cooperations and joint projects as well as innovations in applications and services.
- In the area of providing for daily life, efforts are made to further develop information technology and to enlarge its application possibilities in order to bring about preventive labor and health protection and to expand the range for human-oriented organization of working conditions. The efficiency of environmental protection will also be improved through information technology.
- Investors from all over the world are to become interested in the FRG as a location for production, research and development.
- Obstacles to utilizing technological options which occur in small and medium-sized enterprises will be reduced by means of specific transfer measures.
- In the market sector a decrease in competitive imbalances and trade barriers of all kinds will be sought worldwide; new EC barriers must be avoided.
- The division of labor in the world is best assured through a market-economic system. The conditions for worldwide open competition must be monitored, however, and if necessary improved through government intervention.

**3. Prospective Applications**

The focal points of the support for R&D in the field of information technology will be determined by the future prospective applications for information and communications technology. Among them are:

- Electronic imaging techniques, in particular high-resolution imaging systems (HDTV), display technology;
- Digital ground broadcasting (DAB [Digital Audio Broadcasting]);
- Safe and environmentally compatible transportation systems;
- Improvement in the working conditions and human-oriented job design;
- Computer-supported development, production and logistics in all branches of the manufacturing economy;
- Microsystem technology for minimally invasive surgery or gentle radiation therapy;
- Preventive work and health protection, further development of the level of professional qualification;
- Building a bridge between biology and information technology, particularly with respect to new principles of information processing and biosensors;
- New information systems for environment and environmental protection;
- Creation of the increasingly more clearly evident "networked (informed) society" with its growing demands for quality and security in information processing and communications;
- Telecooperation.

Some important prospective applications will be stressed in the following. They serve as the principal foundation for the derivation of concrete funding concentrations by the BMFT.

**Prospective Applications—3.1 High-Resolution Image Systems, HDTV**

The most important development in the field of high-resolution image systems is the large-screen television of the future, abbreviated as HDTV (high definition television). Compared to the television of today it offers the viewer large images in brilliant quality and a new, wide format, similar to movie film, which is better adapted to the human field of vision.

HDTV involves primarily a qualitatively new television service. But with its high picture quality which approaches that of movie film and photography, HDTV, in combination with data processing, will mainly penetrate into many professional applications beyond the consumer area such as the fields of medicine, education and advertising, printing technology and teleconferencing. HDTV will thus become the engine for a variety of innovations in sectors which make use of visual information and representation.

HDTV is an important lead project for the European information technology industry. Europe still has a viable industrial base in the area of television (in contrast to the United States). The television of the future is the pacesetter for the entire sector of consumer electronics. The strategic importance of the consumer electronics area lies in the fact that this area alone represents the know-how for mass manufacture of electronic high-tech products, a know-how which is just as crucial for the entire PC market as for the mass market of telecommunications and office communications terminal equipment.

Another important connection exists between microelectronics and consumer electronics: In Europe 26 percent of the microelectronics production goes to consumer electronics; looking at the world market, this share is as high as 38 percent. It is no accident that the collapse of the U.S. consumer electronics industry resulted in problems in the microelectronics field. Conversely, in Japan the strong consumer electronics market is the basis for its market power in the microelectronics field.

The success of HDTV is therefore of considerable significance for all of microelectronics. If Europe were to lose the mass market for television, the consequences, particularly for the microelectronics sector, would be grave.

In 1986 30 companies and research establishments joined together under the leadership of Bosch, Philips and Thomson on a EUREKA project (EU 95) in order to meet the challenges of HDTV. By pooling the development resources the European industry succeeded in offering an alternative to the Japanese HDTV system. On the occasion of the Olympic Summer Games in Barcelona and other major events, the maturity of the

European HDTV system was impressively demonstrated. From a technological aspect, EUREKA Project 95 and the BMFT's support are a complete success. It is now the primary task of the industry, the TELEKOM companies and the broadcasting promoters to introduce HDTV and to help this technical success to become a marketing success. The BMFT has therefore initiated a platform from which these partners can promote the introduction of HDTV. On the political level the member nations of the European Community have agreed on a Europe-wide introduction of HDTV and have given the EC Commission a coordinating role for measures on a supranational level.

In the future the BMFT's role will be limited to supporting key technological components and system components for digital HDTV, because the next innovative step in the field of television will be digital HDTV transmission. A joint project called Digital HDTV headed by the Heinrich Hertz Institute devotes itself to this future task.

Strategic contributions to the prospective applications of HDTV are made by the JESSI project in the form of application-specific, highly integrated circuits, concentration on display technologies as well as microsystem technology.

An important task for the future consists of digitizing all image services, including the mass communication services of television and HDTV, in order to meet the continuously growing demands for higher quality and miniaturization of all image, processing and reproduction equipment and to be able to utilize the available transmission channels more efficiently.

**Prospective Applications—3.2 Digital Ground Broadcasting**

The technical standard for today's "analog" VHF broadcasting essentially originated in the 1950s. Meanwhile, digital technology has staged an entry into many fields. Thus, the digital compact disk (CD) has set the standard for improving audio quality (CD quality). Furthermore, today one senses, primarily when driving a motor vehicle, the system-based weaknesses of analog VHF radio that make themselves noticed through reception difficulties.

The enormous progress in microelectronics now creates the technical preconditions for developing the digital audio broadcast system of the future, which achieves the reproductive quality of the CD disk and can also be received in a car without interference. With the EUREKA project DAB (Digital Audio Broadcasting) a proposed standard is being worked out for future digital ground audio broadcasting in a European research cooperation.

After extensive preliminary work, this project was adopted at the Fourth EUREKA Conference on 16-17 December 1986 in Stockholm. Seventeen companies and institutes from seven European nations participate in this EUREKA project. With a total funding of DM 180 million, a European proposal for the new standard is to be worked out and presented to the international standardization committees. German companies and research institutes, which traditionally influence the technical development of broadcasting, are here assuming a dominant role. The BMFT supports the German share with DM 48 million. The industrial work receives 50 percent funding, and the research facilities 100 percent.

DAB forms a seamless continuation of the BMFT's efforts to open up future mass markets in the field of information technology for European industry by supporting R&D at the pre-standardization stage.

The fundamental idea for these pre-standardization R&D projects is to establish the technical standards that point the way with a comparatively modest financial incentive for exploratory R&D work, which, if possible, gathers the European resources within the framework of EUREKA. This work, in turn, is an indispensable precondition for the industry's ability subsequently to be able to open up the mass markets behind the new systems.

The realization of digital ground audio broadcasting is also a first-class technological challenge, however. Converting the complex technical system solutions for DAB into consumer electronics products has only become possible through the progress of microelectronics. The DAB concept requires a series of highly complex integrated circuits in the reception equipment which can be economically produced by using the most modern microelectronics. Due to the large numbers needed in the consumer electronics sector, the mass market behind DAB will result in an enormous demand for integrated circuits with supermodern technology. This wave of demand is of extraordinary importance for the European microelectronics industry, which in the EUREKA project JESSI has made it a goal to maintain a strong European microelectronics base to assure unlimited access for chip users. Without the demand for chips from mass applications such as HDTV or DAB, Jessi itself would lack the necessary economic basis for outstanding technological performance. Insofar the EUREKA projects supplement each other for the standardization and strengthening of microelectronics and help Europe assert itself successfully in important, high-export industrial sectors against the competition from the Far East.

**Prospective Applications—3.3 Telecooperation**

Innovative telecooperation and telepresence systems are created by merging communications technology and information science (to become telecommunications technology). They are the precondition for the increasing use of distributed administrative, management, and labor processes. The trend toward decentralized solutions for organizational, cooperative or information-logistical functions in collaboration between people poses a major challenge to research, as well as to the development of the most modern infrastructures.

Only with the help of an innovative communications and information technology will it be possible to realize a functional and efficient division of labor between work

units separated in space and time. Despite this separation the workers should be able to complete their work cooperatively without limitations. Also, extensive systems-technological support is to be available to them for the cooperative functions. The telecooperations will thus in general lead to a leap in the quality of collaboration between people.

One example is the united Europe, with its major demand for cooperation between governments, parliaments, and administrative units. The same applies worldwide to business enterprises. An obvious first application field in the FRG is the telecooperation system between Berlin and Bonn to support the government and parliamentary functions. The German Bundestag has awarded a corresponding contract for implementation of this information technology system.

Telecooperation is based on information and communications-technical solutions in the three fields of communications, cooperation, and coordination (K3):

- Communications technology must make it possible in the most natural manner and in different ways (cable-guided or by radio, narrow-band or broadband transmission) to exchange multimedia information safely and quickly. Already existing individual solutions are to be replaced by complex integration techniques based on powerful communications networks.
- Cooperation requires user-friendly systems for joint work on the same document (joint editing) and assured access to joint multimedia and distributed information bases. Fundamental research tasks involve working out transparent and, from the aspect of applications, open and compatible systems.
- Coordination is an indispensable precondition for any kind of cooperation based on division of labor. As an independent assistance function in information technical systems, coordination support becomes all the more complex the more extensive the cooperating units and the distribution in space and time of the tasks. Progress in the field of computer-supported cooperative work (CSCW) is therefore an important prerequisite. Designing the system's behavior to conform to human behavior and improving the support for joint work are indispensable elements for the acceptance of these functions.

In order to realize these concepts, the presently available technology is not sufficient by far. An innovative process must be initiated, in which German industry as well can assume a pioneering role.

A comprehensive Telecooperation Program is being prepared within the framework of the BMFT initiatives for the Berlin-Bonn information technology system. It will be designed as an integrating project, in which science and the manufacturing industry will cooperate closely. The Society for Mathematics and Data Processing will bring in its POLIKOM project here.

Early inclusion of the industrial partners is essential, since, for lasting success, it is not only important for science to grapple with important questions but for the subsequent orientation of the research to be aimed at real application challenges and rapid availability of concrete system solutions.

**Prospective Applications—3.4 Building a Bridge Between Biology and Information Technology**

Until now the development of the information technology has primarily been determined by possibilities for technical engineering solutions to the application problems. This is particularly true for the field of pattern recognition and robots. When biological models and methods of application appear useful, one has so far been satisfied with coarse analogies, such as with smaller neural networks.

However, deeper understanding of biological processes involving behavior control could bring distinct progress. This may be expected mainly when attempts are made to take the functional topology of biological nerve systems and their learning processes into more detailed account. In so doing, the functional understanding of neural systems would also experience significant enrichment. But in order to be able to understand the complexity of entire nervous systems and the signal processing in them, close interdisciplinary cooperation is unavoidable.

The combination of powerful parallel computers and evolutionary algorithms has already demonstrated its capability of solving extremely complex problems in many practical applications. With their distributed, subsymbolic and frequently also fuzzy knowledge representation, both neuroinformation science and evolutionary algorithms point out new ways to overcome the boundaries reached in traditional AI [artificial intelligence] research (inflexibility and bottlenecks in rule acquisition with conventional expert systems).

The know-how for successful continued development and application of these algorithms exists in the FRG today. Particularly the processes of collective learning and self-adaptation of strategy parameters form a promising basis for further improvement of the robustness and efficiency properties of evolutionary algorithms in the fields of:

- Technical optimization
- Production planning
- Control of dynamic processes
- Pattern recognition, image construction
- Optimization of neural networks
- Robot control, inverse kinematics

All told, this "biological approach" to information technology can be shown as follows:

**Bioanalogous Strategies for Information Systems**

- Neuroinformation Technology
- Biosensors (integrated sensor methods)
- Learning, bio-electronic interface (adaptive information reduction)

- Bioeffectors (electric eye, nose, feeler, audio system, prosthetics)
- Bioprocessors (neuroprocessor, associative memory based on electronic, photonic and molecular-electronic technologies)
- "Natural computing" networked systems (neural network models, learning strategies, language recognition, fuzzy logic decision models)

**Bioinformation Science**

- Molecular bioinformation science (genome research, protein design, biocatalyst development)
- Evolution strategies (self-adaptive algorithms, self-organization, artificial life)

Research projects in these subjects will be given increased support in the future.

**Prospective Applications—3.5 Information Technology Systems for Safe and Environmentally Compatible Transportation**

Highway, rail and air traffic is of overwhelming importance for the mobility of people and for transportation of goods. In Europe it represents a significant component of the social and economic structure. The individual mobility offered by the motor vehicle and highway network is of great value to the freedom of the individual and to the national economy as a whole. But the high degree of motorization also has tangible detrimental consequences.

**Traffic Safety**

Despite all the progress achieved so far, the number of traffic accidents continues to be high. There is special danger for unprotected persons involved in traffic. A significant increase in safety is a central theme for activities to improve the present situation.

**Environment**

Emissions of harmful substances and noise from motor vehicles affect people and ecosystems. Improvements in this field are important for the acceptance of highway traffic.

**Performance and Profitability**

The limits of performance of the highway network are frequently exceeded. This overloading gives rise to slow-moving traffic and congestion and thus longer travel times, higher fuel consumption and a greater burden on the environment.

The major advances in microelectronics, sensors, telecommunications and information science will pave the way for important improvements in vehicle and traffic technology. They permit solutions which until now were not possible or did not make sense for technical and economic reasons, in which systems in the vehicle correspond with installations by the side of the road. The technical progress enables intelligent vehicles on intelligent roads.

From the research programs of the last few years (PROMETHEUS, DRIVE, etc.) comes a large number of approaches which can be considered for additional research for medium-term application in transportation. The most important elements here are collision avoidance, distance control, digitization of transportation routes and cooperative traffic management, among others, which are supported by the BMFT's Traffic Research Program.

More future-oriented research fields in information science must primarily be aimed at methods to master the complexity which also plays an increasing role in many other economic and technological fields.

Among the R&D questions relevant for supporting information science are:

- Methods/processes for developing/controlling complex systems (reliability of software and hardware tools, standards)
- Image recognition, observation and evaluation, computer vision (radar and optical), algorithms, software
- Interpretation of natural environments in traffic (recognition of human traffic behavior, etc.)
- Systems to support the driver during non-fixed boundary conditions
- Simulation models and associated interactive visualization techniques for crash situations (such as bumper impact for railways).

**Prospective Applications—3.6 New Information Technology Systems for the Environment and Environmental Protection**

The area of issues involving technology/environment represents an important challenge to society today (and undoubtedly in the future as well). Aspects of environmental protection have become a crucial factor in the thinking and in decisions on politics, economics, industry and science. Problem solution concepts and strategies which make sense in the long term can only be worked out based on knowledge of processes in nature and technology and the complex interaction between the two. Both in preparing the foundations and in the practical implementation of the concepts, and finally in monitoring the implementation and success, information science and information technology even today play an indispensable role for monitoring and early warning systems, environmental information and planning systems, in order to mention just a few.

Typical of environmental applications are unusually large, heterogeneous and distributed data and information quantities from biology, physics, chemistry, meteorology and from all technical disciplines, often supplemented by information from economics and administration, which must be acquired, administered, evaluated, and displayed.

A great deal of relevant information accumulates in environmental test networks. Other information sources are biocadastres, data bases in species and landscape protection

and information systems for planning and implementation in administration. Linking the information from these sources, in the future beyond laender and national borders as well, within the developing system of broadband networks opens up problems of interoperability and standardization with respect to communications, data quality, and evaluation and thus—quite fundamentally—the problem of representation and utilization of metaknowledge in the environmental sector.

Large quantities and varieties of data and complex functional relationships require the possibility of compact information storage and display suitable for problems and applications. Here there are close connections with current research efforts in the field of distributed, heterogeneous data bases, object data bases, and geoinformation systems. Current developments toward supercomputer-supported visualization and large-picture display technique are gaining importance here as well. Techniques based on this for the conception of intelligent user interfaces, which enable the non-expert and computer layman to have optimal use of the information systems, are necessary.

The multitude of influencing variables and the complexity of the interactions in environmental applications often result in software systems that are extensive, have a complex structure and are computer-intensive. Here there is further a need for software drafting techniques and tools, particularly from the aspects of portability, reusability and modifiability of the software. Basic questions in this field involve primarily a general coupling of data bases, mathematical models, and the associated evaluation algorithms.

Often a precise representation, sufficient for solving the problems of the complex interactions in the form of closed analytical models is not possible and the problem solutions must be deduced on the basis of empirical and heuristic knowledge. This is where knowledge-based methods find increasing application in decision-support systems, partly also with components for processing uncertain knowledge or for working on multidimensional goals.

For large-area detection and acquisition of environmental damage (forest), methods of interactive high-performance image processing are being developed.

**Prospective Applications—3.7 German Research Network**

In the United States the establishment of computer networks in the scientific field in the second half of the 1970s helped stimulate the willingness to cooperate among scientific establishments and led to new forms of communication with the help of the electronic media being offered. The BMFT took up this idea in 1983, but tied the realization of a network to the use of the internationally standardized producer-neutral norm for open communication (OSI), whose usefulness was thus to be demonstrated for the first time in a large, joint computer system. The science field founded, specifically for this joint network, a network to promote a German Research Network (DFN network), which today has more than 200 members, among them all the universities and major research institutions as well as numerous industrial enterprises.

As a recipient of funding from the BMFT the DFN network has so far established a communications organization with a subsidy volume of DM 75 million, which is used for the exchange of news and data as well as for remote access to special computers in different locations. The success of the DFN project has permitted the DFN network and its technical concept to become a model for comparable projects in the European partner nations. This pioneering role is the essential reason for the creation of the EUREKA project COSINE, which across Europe has led to a linking of national research networks on the basis of a coordinated technical concept.

The DFN network will concentrate its activities over the next few years to setting up a high-performance data network, to broadband European networking within the framework of the EUREKA project COSINE and to coordinating the international network connections. As an additional task the DFN network emphatically pursues the integration of the scientific establishments in the new laender into the German Research Network and the opening of this network, as well as the European COSINE network, to the Central and Eastern European nations.

**4. Subsidy Concentrations**

The goal of the BMFT's research subsidy is to speed up the necessary basic innovations required to realize the prospective applications listed in Chapter 3. In parallel with this, the framework conditions for the future use of technologies, such as the standardization accompanying development and issues of environmental compatibility and safety, must also be taken into account at an early stage.

The following basic innovations are the prerequisite for realizing the above prospective applications.

—Continued Development of Microelectronics Based on Silicon in the Submicron Range

Here is where new design methods are needed for rapid, reliable systems which can be tested and diagnosed, as well as design methods and production techniques for logic circuits, particularly for customer-specific circuits (ASICs). This work is largely being carried out within the framework of the JESSI initiative. A special goal is also the opportunity for small and medium-sized companies to use the design methods. The development of microelectronics provides important stimuli for high-resolution television, high-performance computers and digital communications systems (such as digital ground radio, see 3.2). This subsidy concentration is described in Chapter 4.1.

—Microelectronics and Optical Electronics Based on III-V Semiconductors

The special properties of semiconductors based on III-V compounds enable the integration of electronic and optical components for signal transmission and signal processing. In addition, they permit higher processing speeds. This opens up application fields in the area of supercomputers, navigation and warning systems, traffic control systems as well as satellite television. This subsidy concentration is described in Section 4.2.1.

—Nanoelectronics

With the help of highly developed structuring and growth methods it is possible today to produce well-defined regions within semiconductor crystals. If very small structures are produced with geometric dimensions, perhaps in the size range of 100 nanometers and below, the physical description must increasingly include size-dependent quantum effects. These quantum effects, which could become drastically noticeable in the electrical behavior, offer totally new opportunities for the design of electronic components. Such nanoelectronics can in principle be realized with all semiconducting materials. At this time a few representatives of the III-V compound semiconductors seem particularly promising, but silicon or the silicon-germanium system also show a greatly promising start. This funding concentration is described in Section 4.2.2.

—Molecular-Electronic Memory Technologies

The limits of silicon-microelectronics will probably have been reached with the gigabit memory components. It is possible to achieved higher memory densities through new memory media such as embedded molecular systems. Basic research to ascertain the physical and chemical modes of action of such molecular memories is needed. This funding concentration is described in Section 4.2.4.

—Production and Application of High-Temperature Superconductors

Superconducting offers the basis for new types of principles of function for electronic components and interconnection techniques. High-temperature superconducting can open up the potential for a key technology to increase the performance of conventional electronic systems. This subsidy concentration is described in Section 4.2.4.

—Basic Technologies for Photonics

In photonics the transmission and processing of information takes place with optical and optoelectronic means. The information carrier is light. Due to the very high transmission capacity of optical transmission paths and the opportunity for optical parallel processing, it is anticipated that in comparison with conventional systems significantly more powerful information processing systems can be realized with respect to speed and processed information quantity. Even today optical transmission systems for high-speed information transmission are without competition. Long-term goals are optical parallel computers as well as optical neural networks. This subsidy concentration is described in Section 4.2.5.

—Application of Artificial Intelligence

While the expert systems developed so far have now experienced increasing application in the economy, the future shows an integration of artificial intelligence methods in complex problem solution systems and their combination with neuroinformation for machine learning. Genuine challenges and extensive research fields are also contained in processing natural speech and in image processing. This subsidy concentration is described in Section 4.3.1.

—Neural Networks, Bioinformation Science

Connected with the transition from classical sequential information processing to fine-grained, distributed and parallel storage and processing of information in neural networks is the particular capability of learning and remembering and the possibility for associative supplementation of partial information through knowledge that is present in the system. Such flexible and adaptable systems can be borrowed from nature. They have the greatest prospectes for application. Within the framework of bioinformation support additional learning effects are to be obtained from biology and medicine. This funding concentration is described in Section 4.3.2.

—Massive Parallel High-Performance Calculation

In the next decade information development will be characterized by massive-parallel computer architectures with tens of thousands of processors. This kind of computer promises a 100- to 1,000-fold leap in performance compared to today's vector computers (or fields of work stations). The economy will profit considerably from these developments, since expensive experiments will largely be replaced by interactive simulations. While the corresponding hardware developments are being pursued in a rapid and promising way by the industry, there is a considerable need to catch up in the method and software field, in particular in the application software area. This subsidy concentration is described in Section 4.3.3.

The totality of the basic innovations pursued in these subsidy concentrations supplies the technological foundation for shaping our living conditions in human and environment-oriented ways through information technology. This involves primarily new opportunities for making the cooperation of human and information technology more user-friendly. Optimal utilization of these possibilities in

practice can be achieved when a dialog between developers and potential users can be started at an early stage. For only the potential users are in the position to develop the requirements and criteria which meet the term "user-friendly" in a practical way. An overview of the future tasks of the information technology is found in Fig. 11 [not included].

By working out the funding concentrations, the BMFT is not only following up on its pledge for the Federal Government's future concept for information technology of 1989, but for the first time it combines a concept to promote information and communications technology with the supplementary roles of the BMFT, the R&D programs of the European Communities and the German Bundespost-TELEKOM. The large range of research fields in the area of information and communications technology calls for a concentration of the BMFT's support in areas where research and development in the FRG has strengths and which are also recognized by the economy as promising for the future and strategically important. With the goal of assuring and further expanding the existing strengths in science and industry in the international competition comes therefore a necessarily selective use of national funding in close coordination and based on a division of labor with the EC's growing demands in the future (see Chapter 6), as well as with the projects of TELEKOM, which conducts research and development in communications technology for entrepreneurial benefit (see Chapter 4.5).

### 4.1 Submicron Silicon Technology

#### 4.1.1 Strategies in Microelectronics Development

In the European countries awareness has grown in the last few years that the performance of a single national economy is no longer enough to bring the key technologies offered by information technology to the required maturity on a global scale. This can be illustrated by a figure. The largest European supplier of integrated circuits (IC) is only in 10th place in the world. All three European IC companies together are still smaller than each of the three largest Japanese manufacturers alone. However, this structural weakness of the European microelectronics industry can only be helped by the companies themselves and not through government measures.

A number of companies have joined together on the EUREKA project JESSI (Joint European Submicron Silicon) to mobilize their synergies by combining the research potentials which exist in many places in Europe in subcritical mass. This bundling of resources on the level of research and development is a crucial precondition for assuring the future of microelectronics in Europe. Such a research cooperation is not enough, however, to assure Europe of being a production site and to overcome the structural weaknesses described. The research must be supplemented by a network of strategic cooperations between businesses, which the industrial enterprises must gradually develop on their own initiative.

The leitmotif in conceiving the JESSI research program can be summed up as follows: Acceleration in implementing technological know-how in marketable products. At the beginning of the JESSI program was the identification of market segments, which are of decisive importance for the European industrial landscape; among them are the automobile industry, telecommunications, consumer electronics and the machine tool industry. By analyzing the competitive disadvantages with which these industries struggle in comparison with their overseas competitors when it comes to microelectronics, strategic tasks were formulated in the JESSI program which are oriented toward the research work.

Based on a few outstanding examples for the branches of industry mentioned above, which will not reach their full economic importance until the second half of the 1990s, in JESSI a research program was set up which will improve the cooperation of those involved in developing new systems in the field of information technology. It begins with the system designers and ranges from chip manufacturers, equipment and material suppliers all the way to institutional research which works in these fields. Of major significance in this process is the bridging of the traditionally large gap in Europe between IC users and IC manufacturers. The solution to this problem represents a difficult task even on the national level. To this extent JESSI's mission of improving cooperation between the various participants is an extremely complex task. That is one of the reasons why JESSI does not represent a government-conceived program, but, based on EUREKA principles, from the beginning was designed as a project worked out and organized by the industry itself. (The technological sequence of microelectronics in international comparison is shown in Fig. 12 [not reproduced].)

In conceiving the strategic projects in JESSI the industry has developed the individual work packages from the desired application. It is not the technology which determined the application, but, the other way around, the application, that is to say the future market, which determines which auxiliary technologies are needed. This begins with making more efficient design tools available for the systems engineer, for which future opportunities for new technology must be integrated as early as possible, including the development of the necessary manufacturing processes for chips and ending with making the corresponding manufacturing equipment and materials available which must meet the future demands. Nonindustrial research is given an important role in this concept: It must, in close cooperation with industry regarding the desired goals, work out ways to solve identifiable bottlenecks, research alternatives, and explore the limits of silicon-based microelectronics.

At present about 40 industrial partners and more than 20 nonindustrial research institutions from the FRG participate in the programs.

The funding planned for JESSI is allocated in approximately equal parts on the one hand to the "flagships" listed in the application fields and, on the other hand, to the strategy projects on manufacturing technology including equipment and materials development. However, assuring the indispensable technological basis for application-specific integrated circuits (ASICs) essentially takes place outside the JESSI program. Here it is primarily the most recently agreed-on cooperation between Siemens, IBM, and Toshiba that is of extraordinary strategic importance, since it guarantees the availability of the most modern silicon MOS [metal-oxide semiconductor] technologies until far beyond JESSI.

In addition to the projects defined in the JESSI initiative, fundamental work is being supported in the fields of new circuit structures, new component concepts and design methods as well as the key subject of nanoelectronics, because with the "JESSI technology" and the goals of the Siemens-IBM-Toshiba cooperation silicon-based microelectronics has not reached its industrially usable limits by far. The mesoscopic systems, meaning the transition region between the massive solid state and the nuclear or molecular area, will form the basis for the next segment of electronics—here called nanoelectronics. Here, in contrast to microelectronics, quantum mechanical effects are utilized which at normal temperatures occur only in extremely small structures of the highest crystalline perfection in the range below 100 nanometers. The "nanoelectronics" thus outlined, which could be based on both silicon and on gallium-arsenide, may possibly lead to the first important applications in industry as early as the end of this or the beginning of the next decade. Nanoelectronics is described in detail in Section 4.2.2.

**4.1.2 The JESSI Program**

The JESSI program represents a completely new type of research program. It is not a sum of parallel individual activities, but the integration of various activities into a strategically oriented overall concept under the leadership of the European microelectronics industry. This is reflected in the selection and structure of the JESSI projects.

Even a large, joint research and development program cannot get involved in all relevant areas. For this reason particularly important projects, so-called flagships, have been defined by the industry, which combine the contributions necessary for the research work under one organizational framework. The principal attention is here directed toward rapid exchange of information between the partners involved. The contents of the "flagships" in the application area are oriented toward products which, based on today's view, will reach major market significance at the end of the 1990's.

With the advance of microelectronic circuits into increasingly larger application fields, the demands for the reliability of such circuits are growing, for example when they are used in motor vehicles or in aircraft. Microelectronic circuits for new application areas must still work reliably in rough environments at increasingly extreme temperatures and control higher and higher electrical outputs. Also, the automobile industry, being one of the most important industries in Europe, must be supplied with the required microelectronics in order to be able to maintain the European producers' market share in the long term. Broad application of the possibilities of microelectronics, ranging all the way to small and medium-sized industrial enterprises, is a priority task in order to safeguard the European industrial structure.

Although the application fields for microelectronics described so far cover many different areas, there is a multitude of common problems, the solution of which is the precondition for achieving the specific goals. The JESSI organization has taken this into account with the restructuring of the program proposed in October 1991.

The projects can be divided into two categories:

1) Expansion of the Technological Base:

- methods and tools for circuit design
- manufacturing techniques for integrated circuits

2) Future-Oriented, Application-Related System Solutions in Hard and Software, Integrated on One Chip:

- digital radio (DAB)
- mobile telephone
- high-resolution television (HDTV)
- security-optimized application-specific ICs for the motor vehicle field

In the first group the consortia work with preferably horizontal cooperation. In general, the result of this forms the basis for more vertically structured joint projects by IC manufacturers and users of the second group.

**4.1.3 Methods and Tools for Circuit Design**

The computer-supported design systems for ICs or farther-ranging complete CAD systems which can be obtained on the market today suffer from the lack of compatibility with the individual software packages, which have to be used at the various levels of system design. In principle this applies also to the transition from the design of automatic control engineering behavior to chip design. With a design system called "CAD frame" the European CAD users and suppliers wanted to offer the engineer a working environment which permits him to influence various abstraction levels of the design in a specific way (all the way from chip layout to the spatial arrangements of functional blocks, if possible on the printed circuit board level) and which gives him the freedom to integrate special design tools for his needs into the design system. This presumes an "open" structure. Open here means that the user can supplement his planned

application selectively with his own software packages. The data administration of such a design environment must be subject to certain standards ("standardized interfaces") so that at the various abstraction levels of a circuit design individual, company-specific software can be integrated without expensive adaptation.

In contrast to the CAD systems of today, which at a very early point lock the user's design into a certain technology and thus to one IC manufacturer ("closed systems"), the selection of technology must not take place until a low abstraction level. This has the advantage that the systems knowledge remains as long as possible with the user and the most suitable technology can be chosen at an advanced design stage. A desirable side effect is the standardization of the command sequences, with which the development engineer operates the design system.

This standardization, combined with a simple adaptation of the user's needs, makes it easier, particularly for smaller companies, to use microelectronics in their products.

**4.1.4 Production Techniques**

In order to remain competitive on the world market today, the production of highly integrated semiconductor components must meet in part contradicting requirements. Thus, the pressure toward constantly lower production costs through mass manufacture can be met with more efficient production methods. However, application-specific integrated circuits (ASICs) must be able to adapt themselves flexibly to the demands of end products and be produced for them. Here there is also a demand for flexible production methods, which must simultaneously be economical. An answer to these different requirements is the greatest possible automation of the manufacturing processes. Automated processes deliver high yields and can be adapted to rapidly changing operations. In order to put together a specific semiconductor production line from automated process modules, compatible standards must permit the combination of different equipment blocks. Here, JESSI projects for the first time include many European enterprises, so as from the outset to avoid the previous development of nothing but individual island solutions in the production process. On the contrary; from the beginning a flexible and largely automated semiconductor manufacturing process is to be developed, based on European know-how, which cannot be synonymous with a standardized European CMOS [Complementary Metal-Oxide Semiconductor] process, however.

In order to be competitive worldwide, the semiconductor production methods must utilize the most recently available technologies. This requires the integration of methods to process silicon wafers with larger diameters, the use of new metallization and etching operations as well as the development of new and extremely pure materials. The JESSI cooperation is intended to assure that the individual success will simultaneously benefit the entire European microelectronics industry and that, consequently, a broad basis of reasonably priced European suppliers will be available for user industries.

The JESSI program supports targeted developments, which permit the circumvention of current technological bottlenecks and which significantly accelerate practical implementation of foreseeable technology developments. One fundamental problem in today's production of constantly more miniaturized circuits is error-free lithographic reproduction of tiny circuit dimensions across expanded semiconductor chip surfaces. One foreseeable consequence of the progressing higher integration is that the smallest structures necessarily become smaller than the wavelength of visible light. Known photographic reproduction methods therefore need to be further developed in order to open up possibilities for using even shorter wavelengths (deep ultraviolet) and techniques which take the phase relationships of light (phase contrast) into account in image formation. Here a special JESSI project is beginning, headed by a semiconductor manufacturer in Germany. What is crucial for the goal of this project is that the lithography technique developed in JESSI is being tested early on in semiconductor manufacture and is thus qualified for use in the production of various semiconductor manufacturers. This is where the bundling of developments under JESSI is therefore aimed particularly at accelerating the conversion of physically known methods into production-relevant procedures.

The highly automated manufacture of integrated circuits implies special burdens for the workforce (such as concentration and isolation). In order to reduce these specific burdens, comprehensive improvements are necessary by means of arranging the work organization and techniques. Here as well the increasing problem of the degree of automation, the so-called "residual jobs," must be solved. Such projects can be funded under the BMFT's Work and Technology Program.

**Support for Small and Medium-Sized Companies**

Particularly for medium-sized companies a problem results from the fact that when using specific microelectronic components a portion of the production depth and thus the systems knowledge shifts from equipment or system manufacturers to the component manufacturers, who may possibly produce competing products in their own group and sell on the world market. This danger exists particularly with respect to the Far East competition, when equipment and systems producers do not learn how they themselves can without foreign help transfer their knowledge to chips with the most recent technology. The entire user industry as far down as the medium-sized level is affected by this, for example in the area of measurement, control and drive technology. In order to address this concern a special project was created to stimulate the medium-sized businesses to utilize microelectronics to a higher degree and to raise their competitiveness by using the results gained under

JESSI. Within the framework of this project, demonstration centers are being established at existing institutions in the FRG and put to use according to their background of experience. By arranging information events, seminars and courses the users are gradually introduced to the JESSI technology and modern design methods for highly integrated systems.

In addition to the work started under JESSI, the Federal Government supports further measures to strengthen knowledge about the use of microelectronics in Germany and to include as many potential users as possible. The senate of the Fraunhofer Society has thus decided to reestablish the Institute for Silicon Technology (ISiT) in Itzehoe. The focal points of the work program will be to develop technologies for highly integrated, application-specific circuits (ASICs) and microsystems technology based on silicon. The work includes contributions to the manufacturing technology. It will take place in early and close contact with industry. The work program will be started at the beginning of 1993 at the Institute for Microstructure Technology (IMT) in Berlin. The IMT will then be renamed ISiT-Berlin and after completion of the buildings in Itzehoe move there.

Another contribution to the application of microelectronics is being made by several institutions participating in a north German network. Through this network, consisting of SICAN in Hannover (Silizium-Anwendung und CAD/CAT Niedersachsen), the Institute for Applied Microelectronics (IAM) in Braunschweig and the Microelectronics Application Center (MAZ) in Hamburg, an infrastructure is being made available with which the R&D capacities—such as are offered for example at the academic institutions in the vicinity—will be bundled and strengthened as well as networked with the industrial microelectronics users. The network's concentration therefore lies in supplying advanced engineering and other technical services which are not available or available in a suitable form on the market.

This promotes application of microelectronics, particularly in medium-sized enterprises, by means of carrying out joint projects based on the industrial standard, which are supplemented by pioneering research activities including information, advice and middleman activities. In particular the problems that must be solved in the area of operating funds, artificial intelligence systems for production and order management by users in the small and medium-sized business sector can be reduced through people-friendly design measures such as in the necessary software, the communications interfaces and the flow of information. Here one may expect direct competitive advantages from the comprehensive layout in the sense of the goals of the Work and Technology program (see also Chapter 4.6).

The network model of the MAZ in Hamburg, IAM in Brunswick and SICAN in Hannover permits the coordination of various tasks without therefore depriving the individual facilities of the opportunity specifically to look after the needs of their group of interested parties.

In association with a few other institutes, particularly from the Fraunhofer Society, an offer is therefore available, spread across the entire FRG, to increase the breadth of impact of microelectronics application. The intent is to reinforce the already existing attempts for this in the new laender.

From the former Microelectronics Combine in the eastern part of the FRG well-trained personnel is available for the entire field of microelectronics, so that the personnel bottlenecks often complained of in this sector can clearly be alleviated. For the same reason the BMFT financed a training program as early as the 1980s, in which students were highly trained in the design of integrated circuits (E.I.S. project). The EC Commission has taken up this project and is continuing it as the Eurochip Project within the European framework.

**4.2 New Materials and Technologies**

The strongly expanding application fields in information technology, in which extreme speed, the highest frequencies or the combination of electronics and photonics are becoming increasingly more important, require the development of new basic technologies in addition to the silicon technology. For this purpose the compound semiconductors such as gallium arsenide and indium phosphide have proven themselves, and using them could become a prerequisite for solving public problems.

—Monitoring Environmental Pollution

> The major increase in air pollution from auto and industrial emissions (such as $CO_2$, $SO_2$, nitrogen oxides, ozone, etc.) needs the construction of powerful information-technical systems to detect these gases. In order to produce these information-technical systems with improved detection limits, components such as semiconductor laser diodes, low-noise amplifiers and detectors based on materials from compound semiconductors are important technological innovations.

—Increasing Traffic Safety

> The traffic density on the German autobahns continues to grow due to the annual increase in new licenses for motor vehicles and to the opening of the eastern European borders. In air traffic as well we are seeing an increase in traffic density.
>
> By using modern and highly developed information and communications technology systems the risk of accidents in air and highway traffic can be substantially reduced. Among them are traffic control systems which in every traffic situation contribute to the best decisions on the route and lead to straightening out the traffic flows. Radar systems, which constantly monitor the distance to the vehicle in front and in case of danger or with an insufficiently

safe distance warn the driver through a signal, further increase safety in highway traffic. Fast transmission systems for redundant, central control systems permit analysis of and influence on far-reaching traffic flows.

For such systems electrical and optical components such as semiconductor laser diodes, detectors and microwave circuits based on the materials gallium arsenide and indium phosphide are indispensable, since silicon technology comes up against its physical limits here.

—Image Processing in Medicine

The use of modern, highly developed equipment in medical technology, such as in image-taking and image-processing, results in more extensive and faster diagnosis of people's medical condition. For real-time processing of the considerable amounts of data collected in this field, caused by the high-resolution image technique, the development and use of transmission systems with high bit rates are necessary. Components such as semiconductor laser diodes and detectors of compound semiconductors represent a prerequisite for this. Display techniques must be developed for high-resolution image technology.

The following concentrations are therefore of primary importance for the funding:

#### 4.2.1 Microelectronics Based On III-V Semiconductors

Electronic and optoelectronic components from the III-V compound semiconductors such as gallium arsenide (GaAs) and indium phosphide (InP) display three advantages over silicon components: They switch faster with lower energy requirements, they enable components for higher frequencies and they can receive and emit light—a property which finds multiple applications in optoelectronic systems. Components of gallium arsenide and indium phosphide will, on the one hand, find their application and be utilized instead of silicon components in places where the point is to realize information-technical systems with the highest transmission capacity. These are, for example, superfast computers, navigation systems with millimeter waves, distance warning radar for cars or fast information transmission systems and communications technologies. On the other hand, III-V semiconductors represent the basic technology for optoelectronics and photonics, which are described in more detail in Section 4.2.5.

Compared to silicon, the III-V semiconductor technology still has a considerable lag in development and is therefore only at the beginning of its commercialization. That is also understandable, since these materials can only be produced with extremely costly methods in the necessary purity and crystal perfection. Accordingly, compared to silicon a significantly more complex process technology is also required in order to arrive at an economically favorable production of highly integrated circuits. In this respect there is still a considerable need for research and development expenditure.

Based on the already developed, highly complex facilities and methods in GaAs and InP technology, it has further been possible to reduce the thickness of the individual layers of components to such an extent that layer sequences can be produced in a controlled manner from a few atomic layers, in which quantum-physical effects with new kinds of principles of function for components are possible.

This problem definition is central to the research network for compound semiconductor technology supported by the BMFT and will be described in the following as a part of nanoelectronics.

#### 4.2.2 Nanoelectronics

The precision methods created in microelectronics have been developed so far that structures below 100 nm all the way to a few atomic layers can be produced in a controlled way. In such structures conventional description of the movement of electronics fails; the wave properties of the electron make themselves increasingly noticeable. When the development of electronic components penetrates into this area—also called the mesoscopic—it is necessary to take newer quantum-physical effects into account. Examples of this are the quantum mechanical tunnelling effect or quantization effects necessitated by size. Thus, an electron is capable with a certain probability of tunneling through a thin insulating barrier; according to the concepts of classical physics, on the other hand, it would be impossible to overcome such a barrier.

However, the additional quantum effects can also cause problems for component technologies employed until now, but they offer an opportunity to design completely new elements of function. Such nanoelectronics differ from today's technology not only in quantity because of the advance to still smaller structures, but also in quality, through the use of new quantum-physical effects.

Sharply limited transitions in the semiconductor structures are required for the appearance of these effects. So far particularly III-V compound semiconductors such as gallium arsenide have proven themselves. With defined production of various samples it is possible to make an exact comparison with the statements of the theory.

These advantages have had the effect that basic research, as well as research aimed at application, has so far been primarily conducted in the III-V technique. In suitably structured components it is possible, for example, for electrons to move without scattering in the crystal lattice. With such semiconductor structures so-called ballistic transistors can be produced, which permit a very much higher switching speed than conventional transistors.

Electronic components with mesoscopically small structural dimensions based on Ga As are already reality in

today's laboratory. But basic research is still needed to a considerable extent in order better to understand the physical effects and also to master them technologically. Above all, special methods of process technology must be developed in order to manufacture these components as discrete components or to integrate them monolithically into circuits. The application spectrum ranges far beyond the production of transistors.

For broad industrial applications of nanoelectronics the question of whether systems can be developed which are compatible with the established silicon technology is important. The electronics that depend on new physical principles will also be embedded in a periphery of conventionally integrated silicon technology. Transitions to silicon which are produced through diffusion, for example, are not suitable for vertical nanostructures, to be sure, because they are not sharply enough defined.

At present the material combination of silicon-germanium (SiGe) appears more promising. One example of a component with SiGe technology is the hetero-bipolar transistor. The first laboratory models are already able to compete with the switching speed of GaAs transistors.

These components fall below lateral geometries of about 100 nm and vertical structures of about 10 nm. In the experimental realization of these extremely fine structures, epitaxy dominates for the layer structuring, while laterally the structures are usually made by means of electron beam methods.

The extremely high mobilities and the resulting high switching speeds or frequencies that can be achieved permit the expectation of interesting applications in high-frequency technology. The high integration density possible is also of interest to the further development of rapid digital circuits.

The BMFT's support is concentrated to the basic research that is still needed to a large extent, and it must further search out those options which open up the knowledge from basic research to the application of nanoelectronics. It must be clarified whether potential advantages compared to today's technology can also be realized under the framework conditions of technical production as well as application. This requires research and development in the transitional region from basic research to application-oriented research.

**4.2.3 Molecular Electronics**

Through a continuous increase in the degree of integration with extremely small structures, it appears possible that even gigabit memories can still be produced in silicon microelectronics. For memory densities above that, molecular electronics could be considered.

The electronic and optical properties of molecules from carbon compounds can be used for a variety of purposes in molecular electronics. Among them are memories, switches, molecular diodes, transistors and electrical connections. The existence of these molecules in distinguishable conditions can be utilized for memory applications. The dimensions of the molecular memory can be about 1,000 times smaller than conventional silicon memories. Since molecular memories can also be arranged in three-dimensional ways, the result is a memory density which could be up to six orders of magnitude (one million times) above conventional memory densities.

The development of molecular electronic components is still in its infancy. Components made from organic molecules are so far only being achieved in individual cases. Since the specific electrical and optical approach to the individual molecules has not yet been determined, the work in molecular electronics will initially be limited to basic research. In this concentration two joint projects are being supported, which deal with the production and definition of the material systems and the first potential applications, such as memories.

**4.2.4 High-Temperature Superconducting**

A few years ago the discovery of the ceramic high-temperature superconductor, with application possibilities at the temperature of liquid nitrogen (-196 C°), spurred new research efforts all over the world. Based on this opportunity, the future development of superconducting components in sensors, microelectronics and high-frequency technology must be reevaluated.

Superconducting systems, which are faster, more compact and economical than previous ones, now appear technically feasible. From today's aspect these new, special properties of the high-temperature superconductors allow us to expect many applications in microelectronics.

For example, superconducting layers on silicon or gallium arsenide substrates could be used to increase the transmission speed between semiconductor chips or enable highly dense wiring on chips.

In order to work out these technological foundations for information technology and make them useful for new applications, a joint project called "First Applications of High-Temperature Superconductivity in Microelectronics" has been started within the BMFT's high-temperature superconductivity program.

**4.2.5 Photonics**

By the relatively new concept of "photonics" is meant the transmission and processing of information with optical and optoelectronic means. While in electronics the transmission and processing of information takes place on an electronic basis, meaning with electrons, in photonics photons, that is to say light quanta are used as information carriers. In contrast to electrons, photons do not interact strongly with one another. This property, and the clearly higher transmission capability of optical channels, contributes decisively to the clear superiority of optical transmission in comparison with electrical transmission methods. Photonics must be

regarded as a basic new technology for information transmission and processing and in the future could achieve the same significance for information technology as microelectronics has today.

The development of electronics into photonics is based on progress with III-V semiconductors such as gallium arsenide and indium phosphide. Additional important materials that are gaining importance in this field are polymers for waveguides as well as for active components. These materials and material systems make an integration of electronic circuits and optoelectronics as well as optical components possible, so that electrons and photons would be used in an advantageous combination for carrying information.

One of the most important application fields for photonics is optical communications technology. In electrical communications technology interference effects, such as crosstalk and echoes at high data speeds (after about 100 Mbit/s), cause major problems and make the development of extremely rapid information technology systems difficult. Since photons, in contrast to electrons, cannot interact with one another, optical communications technology can bring a crucial breakthrough for the solution of these problems. Due to the special properties of photons there is also the possibility of realizing numerous independent beam combinations, including those that cross, in the smallest space. With this new degree of freedom optical communications technology becomes a very promising alternative to conventional communications technology, particularly in highly complex electronic systems.

The transmission of information with photons has already become established in beam waveguide technology and proved its economical use above all in telecommunications. In addition to cable-bound transmission of optical signals, they can also be sent through empty space to connect two points. By using appropriate imaging optics, several recipients can be reached at the same time.

The optical signals made by connecting individual components in these complex systems require appropriate signal processing. Here the light signals, for example for switching processes (transmission), must usually be converted many times after one another into electrical and again into optical signals. Each optoelectronic conversion represents a bottleneck which reduces transmission speed. With optical signal processing the goal is therefore to make switches and other functions optical, in order to get components that use nothing but optical signal paths. Due to the extremely high transmission capacity of optical paths and the opportunity for high-grade parallel processing (one lens processes the information of an image in parallel with the speed of light), the construction of very powerful signal processing systems is expected. As a distant goal, an optical computer is conceivable in which a large number of processors are connected through optical communications networks, and where through massive parallel functions significantly higher computing power can be achieved than with today's supercomputers. The extent to which such expectations can be met must be clarified within the framework of research and development projects. Optical signal processing is therefore the object of research and development programs all over the world, particularly in Japan and the United States.

In the funding program called Photonics scientists from industry, research institutes and universities are working closely together on two joint projects in the fields of Optical Communications Technology and Optical Signal Processing. The goal of the R&D work is to research the potential of photonics and to demonstrate it by way of selected experimental systems. In so doing a series of fundamental problems must still be solved. The development of key components based on III-V semiconductors, such as surface-emitting laser diodes, optical switches, optical amplifiers, photodetectors and modulators is also part of this, as is the development of optical multichannel short distance communications systems and new kinds of optical bus systems.

Not until this fundamental research and development work has been completed and the various functions have been demonstrated in practical experiments will additional developments be possible, which today may still be regarded as utopian. With the help of photonics, for example, networks could be created which in function and structure come closer to the nervous system than can be imagined on a conventional, electronic basis.

Optical neural networks is the key word for a new phase throughout information technology; photonics is the basic technology for that. Such thinking will not become reality without progress in the many partial technological areas mentioned. Only a gradual development, building on definite knowledge, will lead further. An abrupt change from electronics to photonics is not the goal, but intelligent combination of the advantages of electronics with the new degrees of freedom of optics must be regarded as the key to success in this field.

**4.2.6 Display Technology**

A significant key element in servicing information systems and machinery in addition to the computer is the display screen. This is what enables a user to obtain access to the information technology system. Examples of this are text processing, bank terminals, displays in aircraft and in the car. In the field of communications technology the following applications are now in use or at present being studied: portable televisions, flat screens, HDTV, video telephone, information systems and medical information systems.

The most widespread cathode ray tubes today are out of the question for the new applications because of their large size, weight, the electrical power needed, and the high-voltage supply. A completely new generation of flat

screens, such as are already being used today in tiny televisions or in laptop computers, must be developed for future applications.

Many technological problems with the flat screen have not yet been satisfactorily solved. But it is already possible to discern that the flat screen will represent one of the most important future markets in information technology. The Japanese industry, led by the Ministry for International Trade and Industry (MITI), recognized the strategic importance of the flat screen early on. The development of a flat screen with the size of about one square meter is being carried out within the framework of a state-subsidized program. In contrast, the European industry still needs to make efforts to bring about a corresponding EUREKA project.

The screens manufactured with LCD technology must be able to compete with conventional picture tubes with respect to gray-scale resolution, color rendition, image-changing frequency, number of pixels, and lifetime. The first equipment made in Japanese research laboratories has already achieved this with a picture screen up to 36 centimeters on the diagonal. For larger diagonals up to one meter, however, considerable research and development expenditures are necessary. Fundamental work still needs to be done in researching suitable liquid crystal materials and their use in coating glass substrates, aging and electrical selection.

The BMFT's support is concentrated on research work on electrical luminescent screens, principally liquid crystal displays (LCD), with new types of liquid crystal materials. For this purpose the initiative of the land of Baden-Wuerttemberg for the establishment of a laboratory for videoscreen technology at the Institute for Network and Systems Technology of Stuttgart University was supported by the BMFT.

In recent years this institute has developed into a talent center in the FRG in the field of liquid crystal videoscreen technology.

**Information Science**

Information science is the theoretical, experimental, and structural science of information systems, their programming and possibilities for application. It was and is a rapidly growing field of science with major innovative force. In less than three decades it has developed from a small scientific seed into a crucial and, for large parts of our economy and society, important factor. It has now become a basic and interdisciplinary field for most developments in science and research, in education, in the economy, technology, public administration, yes, even in the private area, meaning in our entire community. It depends primarily on its research results and their implementation in practical life whether the research results of other disciplines can be converted into useful applications.

Information science research in the FRG, with all of its important application orientations, enjoys a high international reputation, for which, to a significant extent, it can thank the emphatic research support from the BMFT and DFG in earlier years. It is the declared goal for the future BMFT support as well to maintain and expand this research location.

The focal points for information science funding have shifted in the last few years. The center of the funding interest is now the tools and software for opening up new applications for conventional and new computer structures and no longer the development of the computers themselves. Software is gaining an increasingly important rank in the workplace as well, as a technology on a plane above the industries. It influences the productivity and flexibility of all economic areas to a growing extent and thus the working conditions of most working people.

A new concentration for support is bioinformation science, in which knowledge from biological systems is to be converted into information-technical systems. Here the already established neuroinformation science ranks first. The methods of artificial intelligence, language recognition, and language translation are current fields of funding.

One major challenge, with considerable economic impact, lies in the foreseeable availability of super-parallel computers up to the tera-flops range and in their efficient utilization. New mathematical and algorithmic methods for parallelization of the applications and visualization tools for interactive simulations are needed. These activities are summed up under Supercomputing (see Section 4.3.3).

The Reliability of Information Systems is gaining increasing importance as an interdisciplinary task. The relevance of this set of topics is shown in the public discussion on the "correctness of software," "reliability of information systems" and "protection against manipulation," as well as on "computer viruses."

All of these funding concentrations are of eminent importance for the further development of application prospects such as (see Chapter 3):

- Computer-supported development, manufacture and logistics in all branches of the producing economy,
- medicine and an economical health system that corresponds with an international standard of quality,
- environment and environmental protection,
- a safe and environmentally compatible transportation system,
- building a bridge between biology and information technology, particularly with respect to applications in biology and chemistry,
- shaping the increasingly more clearly evident "networked (informed) society," with its growing demands for quality and security in information processing and communications.

**4.3.1 Applications of Artificial Intelligence, Leading Projects**

The concept of Kuenstliche In'elligenz in German linguistic usage is a direct translation of the name Artificial Intelligence introduced in 1956 by U.S. researchers. It was intended to describe a new field whose goals were to be machine understanding of human intellectual performance. In the meantime, it has become obvious that at the core of the ensuing questions the processing of knowledge by computer is a continuation of the previous processing of data by computer. This opens up three fundamental areas of activity:

- The acquisition of application-specific professional knowledge (acquisition of knowledge).
- The formal representation of knowledge (knowledge representation).
- The deduction of conclusions (knowledge processing).

While the previously developed expert systems have now experienced increasing application in the economy, machine learning is beginning to emerge for the future integration of artificial intelligence methods into complex problems solution systems and in combination with neuroinformation science.

Here the research is concentrated to the following fields:

**Knowledge-Based Systems**

Such systems should be capable of:

- linking expert knowledge with problem-specific data,
- dealing with incompletely described circumstances,
- asking for missing data in a specific way or making sensible assumptions about them,
- explaining the courses of action and motivating them.

Special technical requirements in this area are the acquisition of knowledge all the way to automatic knowledge acquisition, knowledge representations in the system and advanced mechanisms for conclusion. To these are also added questions of human-machine interface, distributed architectures for knowledge-processing systems as well as the coupling to conventional data-processing systems.

Knowledge-based systems are at present supported by the BMFT as a concentration at the German Research Center for Artificial Intelligence (DFKI).

An important field of application for knowledge-based systems will in the future be the workplace. Such systems can make an important contribution to the support of complex activities. One priority here—as required in the report of the Expert Systems Inquiry Commission—is to study within the Work and Technology Program how, on the one hand, the potentials of human expert knowledge can be better used and, on the other, experts can be assisted by new systems in their previous activity or for expanded tasks (skilled).

**Recognition and Interpretation of Moving Images**

This research field involves interpretation of image sequences and moving scenes with the help of artificial intelligence methods. With this it is possible to study, for example, how the driver of a vehicle can be assisted by machine interpretation of the road condition and warned in critical situations. This is based on the argument that the majority of serious accidents would be avoidable if the driver had reacted only fractions of a second earlier.

Traffic safety and traffic control can become an important application field for artificial intelligence in future years, because they add new, more intelligent qualities to the well-known solutions.

**Language Recognition**

The need for machines to understand and process language has essentially two reasons:

- the use of language for simpler communication between human and machine (such as in information systems)
- machine language translation.

Computer processing of spoken language is a particularly difficult problem, to be sure, perhaps the most difficult of all in information science and linguistics. Language is very dependent on the speaker in pronunciation and expression, frequently vague in content and depends on the context for its meaning. It is partly redundant, and often greatly abbreviated. In order to be able to recognize, understand, or translate entire sentences, several processing and information steps must be passed at the acoustical, phonetic, syntactical and semantic levels. Largely error-free language recognition requires the immediate cooperation of all levels.

A wrong word does not become noticeable until in the sentence, and a meaningless sentence only becomes apparent on the semantic level. This interlinking of several processing levels is being studied in a joint project (ASL, new Architectures of Speech-Language Systems), in which techniques for recognition of the spoken word (speech) and processing of the content of written language (language) in an integrated architecture are being further developed.

The problem of language recognition is also being tackled under the Work and Technology program. Here there are initial studies, in the sense of evaluating technological results, of successful pilot applications with respect to potential stresses, changes in work content, the work procedure, integration into the operation and human-machine interfaces and requirements for design.

**Language Translation**

A precondition for machine translation of spoken language into another is the recognition and correct interpretation of the language input. The translation system

further needs for the sentences of the original language to be present in a computer-internal representation including explanations of their meaning, in order to be able to transfer them meaningfully into the end language. The way in which this machine operation should appear to the human user is a question of interpretation process and acceptance research which must still be even more thoroughly researched.

Translation systems are large software packages which require enormous computing power. Simultaneous translation equipment in pocket format is not yet technically feasible today or in the near future. That is the very reason, however, that they are a challenging and rewarding long-term task for specific basic research.

The technical progress achievable elsewhere (such as in computer architectures, processors and memories) should lead to implementation, after clarification and demonstration of the fundamental principles, in the form of a mobile translation system. A new master project called VERB-MOBIL is already being funded, which is working toward such a mobile translation system for spoken German language as a future vision. Linguists and information scientists—in particular from the fields of artificial intelligence and neuroinformation science—are to work together on this.

**4.3.2 Bioinformation Science, Neuroinformation Science**

**Neuroinformation Science**

With the transition from classical, sequential information processing to (fine-grained) distributed and parallel storage and processing of information in neural networks is combined the special ability of data-based learning and remembering and the possibility of associative supplementation of partial information through knowledge that is present in the system. Such flexible and adaptive systems are modeled on nature. They have the greatest prospects for application.

In 1988 the BMFT began to support research work aimed at transferring principles of information processing in biology to technical information science. The result was the basic, research-oriented joint Information Processing in Neural Architecture (INA) project. It is based on the hope that a technically adequate solution can be found for a series of tasks which require associative or learning capabilities and occur primarily in the fields of image processing, language recognition, and motor control.

Meanwhile, with the help of research cooperations it has been possible to establish efficient working groups at academic institutions, to bring about close working contacts between people and to achieve significant goals in the first phase.

The second funding phase which has been under way since 1991 involves researching and developing systems that investigate their natural surroundings and can act in it. These systems are to orient themselves with various sensors and be able to react to language input. For this the systems must, to a certain extent, be capable of independent learning. The principal theme thus combines the problem formulations of sensors (recognition of language and images) with those of motor skills (movement coordination).

**Bioinformation Science**

Bioinformation science, in expanding the beginnings of neuroinformation science, involves interdisciplinary integration and cooperation on questions of biology and information science, and primarily:

- Developments of new memory, transportation, and processing systems in information science (further development of neural networks, development of self-organizing technical systems from the analysis of self-organizing biological systems, new visualization techniques, etc.), which are derived from the knowledge of biology,
- goal-oriented new development of information and mathematical methods and techniques for processing unsolved problems in biotechnology (such as development of special parallel algorithms for biological data bases, development of special knowledge-based systems for the analysis of proteins, etc.).

This can be explained using the following two examples:

For the development of biotechnology, the decoding of the entire genetic information of living things is of major importance. Over the next 10 to 15 years it is to be explored in detail for individual cases, according to the plans for various international genome research programs. The anticipated enormous increase in genetic sequential and structural data reinforces the already evident imbalance between data quantity and data processing. Here, on the one hand, the development of new methods of data gathering and administration is needed, and, on the other, new approaches to the interpretation of the data must be found.

Protein design demands new mathematical and information methods. The application potential of proteins which have been deliberately equipped with new properties cannot be overestimated. In this context one can merely point to the development of bioreactors, the decrease of harmful substances, new drugs and vaccines as well as biosensors. Precisely in protein design; however, the present simulation methods come up against their limits due to the size of the molecules involved and the complexity of the relevant interactions with respect to their computing speed and graphic representational speed. New algorithms and computer techniques, which transfer the principles of the multigrid methods so successful in technical simulation to the problems of protein design, must be developed.

Analogous reflections can be made for a whole series of scientific disciplines. In the following section they will be described under the concept of supercomputing.

#### 4.3.3 Supercomputing

Supercomputing, that is to say the treatment and solution of complex scientific and technical problems by mathematical modelling and simulation using supercomputers, is awarded the rank of an independent scientific method. Over the next decade computer development will be marked by massively parallel systems with tens of thousands of processors. This kind of computer promises a leap in power from 100 to 1,000 (teraflops computers) compared to today's vector computers (or fields of work stations). Science and, in particular, the economy will profit considerably from these developments, since expensive experiments will largely be replaced by interactive simulations.

While the corresponding hardware developments are progressing quickly and with a great deal of promise for success, there is a substantial need to catch up in R&D in the software sector, especially in the area of application software.

The application prospects for teraflops computers in materials research, in flow and turbulence research, in molecular chemistry, in biotechnology, in pharmaceuticals, in weather prediction and in climate research are so important, that the economic gains from later application of such computer systems are likely to far outweigh the R&D expenditure now involved.

In addition to the application areas mentioned, the development of parallel computer technology will have significant impact on industrial applications even in the short run, above all in the real-time area, as for example in industrial control (particularly for robot control), in machine understanding of image and speech, in automobile electronics, etc.

It is foreseeable that in the abovementioned fields in the future nearly all experimental solutions can be replaced by:

- new, high-resolution modelling,
- algorithmization and programming for massively parallel computers,
- interactive simulation with real-time visualization in these computers.

According to today's findings, with respect to application, modelling, parallel algorithms and parallel programming, the potential is there for increasing the performance similar to the hardware development of the supercomputers themselves.

Close interdisciplinary cooperation is indispensable between the basic sciences of:

-Mathematics: for the development of new parallel solution attempts

-Information Science: for offering architectures, methods and tools for efficient and secure implementation of parallel algorithms

-Application Sciences.

In the coming years the BMFT intends to fund key method problems in supercomputing by means of concrete application questions. In so doing it presumes that highly parallel supercomputers up to the tera-flops region can be made available by the industry in the next few years without national subsidies.

The BMFT's funding concentrations are, in agreement with other programs (EC, laender, DFG) in the following areas:

- Tools for converting existing application software to the new, parallel systems, which permit rapid and economical conversion even of extensive program packages.
- Tools for developing application software for parallel computers, flexibly manageable tools to support all drafting phases from specification and verification, through mapping, fault search, performance indications and visualization, all the way to runtime support using dynamic load equalization mechanisms.
- Development of standardized programming interfaces, which assure the portability of application software between systems of different configuration and between different parallel computer architectures.
- Rapid parallel algorithms for supercomputers, for example in real-time simulation of applications with supercomputers.
- Reliable and secure supercomputer connections, with a transmission speed of up to the Gbit/s range, at affordable prices.

The BMFT will describe the individual subsidy measures and the overall framework once more in a detailed special pamphlet.

#### 4.3.4 Reliable Information Systems

Almost all areas in the economy and administration today depend directly or indirectly on the functioning of information processing. The breakdown of a computer, errors in a data processing program, or the loss or manipulation of data can bring complete production or administrative sectors to a standstill and cause widespread damage as a result. The individual citizen is also affected when personal data are manipulated or spied on.

Funding security and reliability in information processing is therefore a task for the government's role of caring for our well-being. Here the BMFT and the Federal Office for Security in Information Technology (BSI) are working together and supplementing each other. The BSI is charged with developing methods and tools for testing the security of information technology systems and components. After appropriate evaluation, it issues security certificates. The BMFT supports the preceding research work and developments in information science as a concentration with the goal of reliability against manipulation attempts and correctness of the programs produced (quality assurance for software).

The BMFT's research support is initially concentrated to the two leading projects REMO and KORSO.

The joint Reference Model For Secure Information Technology Systems project (REMO) has two R&D approaches:

In the constructive approach, today's functions and communications paths in a computer system will be deregulated and redefined under the aspects of security. The result is to be a formal description, a "reference model for secure systems," supplemented by a guideline for future developments of information systems, taking their technical and organizational environment into account. To begin with, the performance goal for this is intentionally and deliberately of less importance than the security.

A second, topical approach in REMO (supplementary approach) is being taken for the widespread use of PC systems and workstation computers in order to improve the security situation faster. The attempt here is to add security mechanisms which can be retrofitted to the existing technical interfaces. For example, a user interface supplied by the manufacturer can be replaced by another which no longer permits access to all functions of the information system. This way it is possible to prevent circumvention of the built-in safety measures.

In the joint Correct Software program (KORSO) the instruments of the specification languages and the machine proofs can be connected with one another. Based on the task specifications, a data processing program is to be gradually more finely defined until ultimately the actual program code is obtained. Each individual step is thereby to be tested with the help of proof algorithms with respect to its formal correctness. The final conclusion is:

When the output specification precisely and completely describes the task to be solved and when the development steps derived from it have been individually proved by machine to be formally correct, then the result, that is to say the program code, will also be correct.

This project is thus an important step in the field of quality assurance for software.

### 4.3.5 Software Technology

Both past and foreseeable developments unequivocally indicate that software—to an even greater extent than hardware—will continue to gain importance and become a dominant economic factor. It occupies a special key position as a basic technology, on which the development of many other fields—not only information science—are directly dependent. Despite the successful work within the framework of previous subsidy programs, numerous fundamental problems have not yet been solved in useful form, or new questions have been added. In this context one might mention specification, portability, reusability and modifiability, and the organization of complex, distributed software systems, as well as questions of machine verification.

In all, the focal point of future R&D tasks lies in mastering the complexity of integrated overall software.

**Design and Testing of Reliable Complex Overall Systems**

Support for the design of reliable overall systems (technical components plus software) is an important concentration for future research. Since computer systems are increasingly being centrally used for critical applications, it is necessary to guarantee as early as the design stage certain important properties such as operational security, security against catastrophic errors, robustness against breakdowns, ease of testing and ease of altering. Corresponding tools for the specification, design and implementation, as well as for performance measurement and machine verification, with simultaneous documentation and quality assurance must be developed, or the existing attempts must be integrated and tested.

**Reduction of the Program Steps**

In order to master the overflowing complexity of large software systems with millions of lines of code, the software must be designed in significantly more modular form than before, which also increases reusability. Reducing the number of coding lines to be created and controlled by the programmer must be further advanced through new, usually object-oriented programming languages.

**Software Reusability and Software Reengineering**

A basic problem in the economy is the constantly required adjustment of existing software packages to new tasks or framework conditions and software reusability in the development process. In this context, questions of documentation of reusable software, the adaptation of software to current applications and methods, tools and techniques for software reengineering are assigned major importance. So far there has been only a small number of method foundations and research projects in these subjects.

**Software Factory Master Project**

An important part of the R&D work in software technology is already being done in the current EUREKA Software Factory project (ESF).

The goal of this project is to improve the foundations for industrial-scale software production and to standardize it. The concept of "factory" in the project's name expresses that a production process for software generation is to be sought which is comparable to the production of other industrial goods. Such a procedure presumes new work techniques and organizational concepts, new methods of software engineering and, above all, powerful software tools.

The necessary know-how can only be obtained in a European cooperation within the framework of EUREKA, by involving academic institutions, research establishments and industrial research divisions.

**Software Developments for Parallel Computers**

Reference is made to Section 4.3.3.

**4.3.6 Problem-Oriented and User-Adapted Software Design**

If the opportunities of software technology are to be more heavily utilized based on competitive aspects, more consideration for application prospects in the form of problem-oriented and user-adapted software will become particularly significant. Within the framework of the Work and Technology program on an interdisciplinary basis, important incentives have already been launched in the past to find out and implement the requirements for software. While stressing the user and subscriber perspectives, in the future it must be possible to ask the question of how software should be designed in order to create optimum load working conditions which promote creativity, skill and personality in the production as well as administrative and service sectors. Special attention is here focused on newer developments in information technology for the workplace such as distributed systems, communications networks, software to support group working models and expert systems for the support of complex activities.

In addition, there will be a continuation of the already begun efforts to offer the software development process itself tools and methods (such as through supplementation of existing CASE tools, through methods for greater participation of end users and through corresponding offers of skill improvement for the developer), which will make it possible to include the criteria for problem-oriented and user-adapted software to a greater extent.

**4.4 Microsystem Technology**

Microsystems are miniaturized products which are able to acquire and evaluate data and take action independently. Sensors correspond to the human senses, signal processing the brain and actors the extremities. In their manner of function they have been modelled on nature.

Microsystem technology contains the set use of:

- miniaturization techniques, which include not only the electronic field (such as semiconductor technology, layer technology) but also the optical field (such as integrated optics, fiberoptics), the mechanical field (such as micromechanics) and the biological field (such as biosensors, enzymes, antibodies and receptors as biological detection component),
- architecture and interconnection technologies which permit combination of individual components,
- system architectures and signal processing concepts which support the integration of various microtechnologies into systems,
- system technologies which enable complex product developments through computer-supported tools for analyses, design tools and simulation.

Microsystem technology promises a major potential for the improvement of existing products and for the development of new ones. Even today sensors, actors, installations and tools for their design and production reach an annual turnover of several billion DM in the FRG. Many small and medium-sized enterprises, which have now achieved a strong position specifically for demanding and user-oriented products that are tailored to a small group of customers, are working in these markets.

Considerably larger, however, are the markets for products for which these components represent crucial factors in the competition. They include many of the technology-intensive and heavily exporting branches of German industry, for example mechanical engineering, the electrical industry, motor vehicle industry and the chemical plant construction industry. In the following application fields, for example, the use of microsystem technology will lead to faster, safer, more precise, and cheaper solutions:

-Microsystems will enable improved path welding methods in production and thus improved welding seams which have higher resistance to corrosion.

-Cheap and simple optical microsystems, used in traffic control technology, open up the possibility of guiding vehicles to avoid traffic jams.

-Microsystems using the effect of radiation on human tissue, can, when implanted, control the dosage effect in cancer radiation therapy and thus reduce the previous dangers of excessive dosage or damage to healthy, surrounding tissue.

-Large-area advertisements and screens, composed of many small individual components obtained by using microsystems, improve resolution precision and permit the use of large-format video displays, for example in traffic control centers.

-Microlasers, use for trace analysis, permit better chemical analysis in environmental monitoring and better food control.

-The use of microsystems in heating elements in private households allow for optimum control and regulation of the heat supplied, according to the individual requirements of the occupants. They can therefore make a significant contribution to saving energy.

Successful use of the opportunities of microsystem technology in companies requires the solution to a series of problems. In addition to being able to finance risky product innovations, it is mainly a matter of technology management ability. The experience from introducing microelectronics has clearly shown that innovations in a part of the company have major impact on other parts. The introduction of microsystem technology is many times more difficult than that of microelectronics. The employees are forced to think in systems if microsystem technology is to be made useful for product innovation. Therefore, microsystem technology acquires a key function beyond the technologies for improving innovation management per se.

The Microsystem Technology subsidy concentration which began in February 1990 targets small and medium-sized enterprises for the additional reason that when using new

technical options they come up against the limits of their capabilities faster than large companies. Depending on the manufacturing process, certain microtechnologies result in typical minimum quantities, for example, which must be achieved per year on a production line if the investments are to be profitable. For small and medium-sized enterprises it is therefore not sensible from economic viewpoints to set up complete design and production in their own companies from several of the modern process technologies with microsystem technology. For this purpose a powerful network of technical services is needed that also includes the participation of major companies with the corresponding infrastructure, which also enables the small and medium-size enterprises to make use of the most modern technologies.

The various microtechnologies used in microsystem technology, and the systems technology itself needed for their intelligent linking, are developed at universities, research establishments outside universities, and at research laboratories in major industrial firms on a laboratory scale. Although public funds are made available for this in many forms, it is by no means assured that the results, on the one hand, are systems-capable and, on the other, manageable by small and medium-sized enterprises in such a way that the products resulting from them meet market demands, for example in quality and reliability.

For the years 1990-1993 the BMFT is supporting, with a grant volume of DM 400 million, a bundle of funding measures which are interlinked with one another in content and which are to support the initiatives of industry itself:

- support for joint projects
- indirect-specific support
- support for technology transfer and cross-section projects

Joint projects by small and medium-sized enterprises and research institutions are to close gaps which until now have hindered the use of microsystem technology for product development in these companies. To a limited extent large companies can also receive funding within the framework of joint projects, if they contribute indispensable know-how or declare themselves prepared to supply the technologies to be developed within the framework of an implementation concept for small and medium-sized companies.

Up to August 1992, 31 joint projects with a total volume of DM 151 million had been approved. Applications or project outlines for additional joint projects with a volume of approximately DM 80 million have already been received. This shows that—contrary to the prevailing opinion—it has been possible to construct joint projects in such a way that they are interesting for small and medium-sized enterprises even with a total subsidy ratio of between 30 and 50 percent.

The starting point for the indirect-specific support is the development of prototypes. This no longer involves a closely defined new technology but solving the many tasks of innovation management, that is to say selecting and mastering a number of technologies which can be used to create microsystems. For the first time, projects are being awarded to third parties for qualification and organizational adaptation in order to create the prerequisites for rapid development, production and market introduction of the new product.

For the indirect-specific subsidy measure the number of submitted applications in the first 13 months of the program period for the Microsystem Technology subsidy concentration was three times higher than expected: 535 companies handed in applications for the development of sensors, actors or signal processing components. After the subsidy policy goal of creating an incentive for innovation in the companies had been achieved sooner than originally expected, the acceptance of applications for this subsidy measure was stopped on 19 March 1991. DM 114 million had been granted as of August 1992 for this measure.

In evaluating the indirect-specific measure, it has turned out that the companies use half of the funding to apply technologies for product innovation which until then had not been relevant for the company.

The support for such technological leaps was started beginning in 1992 by the BMFT with a general R&D lending program for such businesses.

By August 1992 DM 32 million had already been made available for microtechnologies from this program.

Technology transfer has a central significance for microsystem technology. The results for joint projects, from other specialized BMFT programs, from relevant R&D activities here and abroad are to be made available to the small and medium-sized companies in a prepared form. Particularly useful in this context are: technology reviews, which are already available on the market, and service centers at research establishments with technology advisers.

A range of services for all relevant technologies such as fiberoptics, micromechanics, installation and connection engineering, as well as for signal processing concepts, test methods and standardization, already exist. The service centers are supported with funds which will be completely abolished in a few years; after that the centers will have to survive in the service market.

As supplements to the funding measures mentioned in the Microsystem Technology funding concentration one should mention the involvement of the major research institutions themselves, above all the Karlsruhe Nuclear Research Center (see Section 7.1.2). The Fraunhofer Society as well aims increasingly more in the direction of microsystem technology (see Section 7.1.3).

An accompanying evaluation and assessment of this funding concentration is provided for the decision-makers in the industry and at the funding agency through topical information about the present diffusion of microsystem technology and the level of research and development in microsystem technology, as well as about gaps which must be closed through selected research and development.

Many research establishments and enterprises in the new laender have good opportunities for starting off in microsystem technology. The VDI/VDE Technology Center for Information Technology has already been able to arrange many cooperations with western German firms in the fields of development, production, operation and service. Joint cooperative projects are now the rule for applications in the Microsystem Technology funding field.

Financial support for companies and research facilities can always develop its full effect when the environment is right. It is therefore welcome that more and more academic institutions and universities are putting microsystem technology on their list of courses. So far, four polytechnic colleges (Regensburg, Munich, Esslingen, Mittweida) have established a special subject of microsystem technology, and at least three more polytechnic colleges entertain such plans. On the academic level a study concentration of Microsystem Technology already exists at Ilmenau Technical College and at other colleges the establishment of chairs and study concentrations are under way. Freiburg University stands out in this respect, which together with the Karlsruhe Nuclear Research Center is establishing a new center for microsystem technology as well as a technical field of microsystem technology with 15 chairs.

This research concentration is to be continued for the years 1994-1999. The Second Integration Phase for Microsystem Technology will be in the foreground, meaning the inclusion of biosensors and system-controlled technology development for sensors, signal processing and actor systems. Since the greater part of German industry lives from integrating information-technical components into products and it consists primarily of small and medium-sized enterprises, the level of microsystem technology and its diffusion will develop into an indicator of international competitiveness.

**4.5 Telecommunications Research**

**4.5.1 Reorganization of the Research System in the Field of Telecommunications**

The concepts of the Federal Government on research and development in the field of telecommunications have been stated in the Concept of the Federal Government on the Reorganization of the Telecommunications Market passed in May 1988 as well as, following that, in the Future Concept for Information Technology (August 1989) in connection with the overall strategy for the development of information technology.

The BMFT's support relates to materials and technologies (see Chapter 4.2) and to application fields such as HDTV and DAB [Digital Audio Broadcasting] as well as to institutional basic research. With a view to TELEKOM's activities, the orientations of the future concept are:

- DBP TELEKOM's research should clearly be intensified (see also Postal Constitutional Law, Article 4 [1]), in order to enable it to change the quality of the telecommunications services in its own business interest and in the interest of the customer. In so doing, a concentration of the efforts to applications and services should take place.
- By intensifying its R&D, DBP TELEKOM should be placed in the position of being able to evaluate worldwide technological innovations in telecommunication in user practice, in order to find the current needs for constant modernization of its telecommunications networks. Against this background it should make an important research contribution to the national economy and to society.
- The buildup of R&D capabilities at DBP TELEKOM should not occur with the objective that the enterprise itself should produce hardware.
- The buildup of DBP TELEKOM's own research should neither compete with nor substitute for but supplement ongoing research activities in the private economy and publicly financed research.

Based on these concepts, DBP TELEKOM at the end of 1991 presented a framework for its future R&D activities and coordinated it with the responsible federal ministries.

**4.5.2 Framework Ideas for DBP TELEKOM's R&D Concept**

In the Federal Government's Information Technology future concept and in the law on postal organization, statements have been made about the future research activities of TELEKOM. Accordingly, it says in Article 4, Section 1, of the Postal Organization Law:

"... In order to fulfill their duties the businesses must carry out research to the appropriate extent."

The Federal Government's Future Concept for Information Technology establishes the following for TELEKOM's research:

"TELEKOM will have research fields in the infrastructure area: this is where research must be carried out in order to be able to implement a modern telecommunications network economically and safely for the future, according to the demands of the economy."

"But TELEKOM must also be supplied with research results in the competitive sector, so that it can survive in the market. In so doing it will rely as much as possible on research achievements which are available on the market... Mainly, the need-oriented (services and applications) and the network-related research activities must be strengthened. Also to be intensified is the software field with a concentration on Software Engineering, as a centrally necessary know-how for a TELEKOM that is also part of the competition..."

Following the concept in question, the TELEKOM's research is composed of activities at the research institute (FI), at EKOM (Development and Testing of Broadband Communications Systems), at BERKOM [not further identified], and at EURESCOM [not further identified].

With its projects in R&D, TELEKOM is pursuing the basic objectives of:

- synchronizing the research concept with long-term business goals
- concentrating its research mainly to future network concepts, network components and services,
- raising the efficiency of the research activities through selection and organizational structures
- increasing joint and contract research and thus its flexibility
- accelerating the implementation of research results.

As a derivation from business strategy, the research activities concentrate on networks and network-related basic and special services as well as application-related special services.

Studies of market development potentials and technological evaluation are to be added on a broad basis. On the other hand, the research is not expanded to the field of basic technology, because the extent of these activities is more to be regarded as subcritical. Here the aim is toward streamlining and cooperation with other European network operators. Research and development of software in the telecommunications sector must be intensified, however.

Thus, in the future one will proceed with three research fields:

- future networks in the core area,
- future services
- market development potential/technology assessment for the total enterprise.

TELEKOM's research should be designed for innovation as well as to help optimize operational processes. In addition, in the new Market Development Potential/Technology Assessment research field there will also be technology assessments undertaken in order, among other things, to recognize and discuss the social effects of future telecommunications services as early as possible. On the first three levels of the R&D chain TELEKOM's research will a) generate, interpret and evaluate knowledge; b) formulate options and ideas; c) work out studies/simulations of networks and services and obtain knowledge on a longer-term time scale, concentrated and in its own enterprise (in-house research), jointly with third parties (joint research) or, contracted for by TELEKOM, by third parties (R&D contracts).

TELEKOM's research is divided into four partial areas:

- Networks
- Services
- Joint/Contract Research
- Market development potential/technology assessment.

The TELEKOM's research concept is published separately by the enterprise. The planned R&D spending for the years 1991 to 1993 is shown in the following table.

Through the procurement policy and infrastructure measures of DBP TELEKOM additional incentives for innovations and for opening up new markets in information and communications technologies are to be created. An example of this is given by the establishment of a communications network based on optical waveguides in the new laender.

**R&D Spending by TELEKOM 1991-1993**

| | 1991 | 1992 | 1993 |
|---|---|---|---|
| | million DM | million DM | million DM |
| **Research** | | | |
| Market/Technology | | | |
| Research Institute Projects | | | |
| Projects: BERKOM | | | |
| EKOM | | | |
| EURESCOM | | | |
| Total Research: | 155.0 | 231.5 | 280.0 |
| Of which personnel costs | 48.0 | 54.0 | 60.0 |
| **Development** | | | |
| Innovation Procurement | 356.0 | 501.0 | 630.0 |
| Of which personnel costs | 42.0 | 46.0 | 50.0 |
| **Total R&D** | | | |
| Total R&D | 511.0 | 732.5 | 910.0 |
| Of which personnel costs | 90.0 | 100.0 | 110.0 |
| **R&D in percent of turnover** | | | |
| Total R&D | 1.1 percent | 1.5 percent | 1.7 percent |

### 4.5.3 Elements of the Research System in the Telecommunications Sector

The research system of the telecommunications sector in the FRG after the postal reform is made up essentially of the following three elements:

**Government Measures for Research and Development**

The government research field has a competent research facility in the Heinrich Hertz Institute (HHI), whose areas of work can predominantly be classified as telecommunications research (detailed project description in the Future Concept for Information Technology, p 174 ff.) Conceptually closely linked with the Heinrich Hertz Institute are national cooperative research programs by the BMFT, such as are described in Chapter 4.2. "New Materials and Technologies."

In these government-subsidized joint programs basically new technologies for application fields in overall information technology are developed, particularly in areas where extreme speed, the highest frequencies or the combination of electronics and photonics are important. Prospective applications in telecommunications will also in the future be more extensively based on these new technologies and thereby make new, intelligent system solutions possible.

For example, it is the goal of the cooperative projects in the field of photonics to develop the required fundamental technologies for later use of optical communications technology in modern telecommunications systems. (The details are described in Chapter 4.2.5.) Beyond that, and complementing the research programs of the EC and the entrepreneurial R&D measures of TELEKOM, future-oriented systems work is being supported by the BMFT. Examples of this are the activities for digital audio broadcasting, DAB, or developments in the field of digital television.

The international research components are represented by, among others, the EC programs RACE and TELEMATICS, whose vital objective is marked by offering the technical foundations for a future integrated European broadband communications network.

**Industrial Research and Development**

Industrial research and development in the telecommunications sector in the FRG has traditionally been strong in international comparison. Unlike in France or the United States, where telecommunications research was largely carried out and funded by the network operators, in the FRG telecommunications research has been the domain of the industry. This will remain so in the future.

**Research and Development by TELEKOM**

After the postal reform the Federal Ministry for Posts and Telecommunications had an immediate impact on the research of DBP TELEKOM. According to Article 25, Section 1, of the Postal Constitutional Law, the Federal Minister for Posts and Telecommunications determines the medium and long-term goals for the DBP enterprises that are so important for the development of the postal and telecommunications system and for protecting the political principles of the FRG. This applies also to demand-based further development in the quantity and quality of the telecommunications infrastructure. Starting with the appropriate guidelines, DBP TELEKOM on its own responsibility derives the measures which are necessary for implementing the goals that were set. This applies also to the measures in the R&D area.

In formulating its research concept TELEKOM must take these framework conditions into account. Thus, TELEKOM's R&D activities, as suggested by the BMPT [Federal Ministry for Posts and Telecommunications], become the third element in the overall research system of application-related R&D work. They range from internal company research work at TELEKOM's research institute to pilot projects in the field immediately before subsequent acquisition.

TELEKOM's research and development strategy is primarily oriented toward business interests. But at the same time it is also supposed to be constructed in such a way that the TELEKOM's activities supplement the BMFT-supported research on the one hand and industrial research on the other: TELEKOM's R&D makes use, as much as possible, of the publicly funded new technologies, picks up on approaches that are interesting to the company and develops these in the direction of later application through, for example, focused R&D projects. During the course of such R&D projects, which are mainly carried out by industry, the TELEKOM's R&D strategy is to be interlinked with the R&D activities of industry. In so doing, within the framework of what is permitted in competition, direct collaboration such as cooperations or joint enterprises are possible. Corresponding pilot projects based on that can be agreed on for testing the network technologies.

### 4.5.4 New Communications Infrastructures

Communications networks play a key role in today's information society. They form the infrastructure for networking user terminals, computers and computer-supported systems, and they find uses, for example, in data base, reservations and information systems as well as in production facilities with robots and control centers. To the conventional utilization forms of language, text and data communication, are increasingly being added high-resolution fixed image and moving image transmission, faster exchange of mass data and multimedia communication. Many other uses in the economy are already evident. Among them are telecooperation, integrated development, on-line visualization of simulations with supercomputers, remote monitoring of technical systems or integrated acquisition and evaluation of measurement data for environmental protection. A significant expansion of the utilization possibilities is also anticipated with mobile end equipment.

The demands placed by the various application forms on the communications infrastructure display enormous differences with respect to bit rate requirement, connection configurations (point-to-point, multicast, broadcast, group communication), network intelligence for communication with mobile participants and network quality in the form of blocking and delay behavior, reliability and data security quality. These demands and requirements for economical use of the networks are expressed in the following development guidelines:

- Service integration,
- interoperability of network types and systems,
- intelligent network management
- international standardization (OSI [Open Systems Interconnection] norms, CCITT recommendations).

By means of internationally extensively coordinated and established processes, the development lines run in quite clearly recognizable directions toward local and regional high-speed networks (Local Area Networks, LANs, Metropolitan Area Networks, MANs) as far as the Gbit/s range and to high-speed, long-range networks based on ATM (Asynchronous Transfer Mode), attached to a network infrastructure based on optical transmission technology (Synchronous Digital Hierarchy, SDH). While in these developments all the logical control functions are realized in a way that uses nothing but electronics and software engineering, in the future new, basic technologies with purely optical transmission technology (photonic switching) will make expansion into the ultrafast range possible through optical signal processing. These developments are superimposed by the requirements of mobile communication (very small communication cell ranges in the GHz region, intelligence network control, vehicle communication) and long-term planned integration of pure distribution communication (digital broadcasting and digital television).

The precondition for the acceptance of new forms and possibilities of communication is testing at an early stage. Here, for example, the scientific field makes itself available as a user organization, since this is where demands for higher quality often originate, such as access to a few supercomputers via fast communications networks, worldwide access to scientific data bases, cooperative development, teaching and learning, as well as global electronic mail (e-mail), in which particularly the problem of interoperability quickly emerges. These opportunities, although initially just in the field of narrow-band transmission networks up to 2 Mbit/s for pilot testing, were answered by the establishment of scientific networks. In this connection the BMFT supports the German research network DFN and the European research network COSINE within the framework of the EUREKA initiative.

By advertising in the subject categories of regional test beds for high-speed communication (applications and MAN technologies), network management, and multimedia communication cooperative projects between industry and scientific institutions are organized through the DFN association.

This also includes the potential of the academic institutions, which are intended for solving problems in the area of methods, and which through their connection with teaching are also able to assure high-quality training of the next scientific generation.

The pilot experiences collected in the scientific sector should then rapidly be transferred to additional representative application fields, so that development lines and introductory strategies can be identified in order to provide for a future information and communications infrastructure.

### 4.5.5 Reducing Competitive Imbalances in the R&D Sector

To supplement the activities in the field of research policy mentioned above, the Federal Government will steadfastly continue to pursue its efforts to eliminate international imbalances in competition due to financing methods for R&D that vary from country to country. In view of the complexity of this problem and taking into consideration the time frame until satisfactory solutions can realistically be achieved, it is necessary to develop a concept for avoiding disadvantages in location for companies active in the FRG. Pertinent discussions are being accelerated principally on the part of the Federal Ministry for Posts and Telecommunications and of the economy.

### 4.6 Information Technology and the Workplace

The structural change in the modern industrial nations is now triggered by changes in the labor potential (demographic development, shifts between employee groups, changing concepts of value), by changes in national and international competitive situations, by the development of new production and distribution concepts, as well as through the development of new technologies and materials. On the one hand information technology is an important trigger factor for this structural change, and, on the other, the structural change for its part poses demands on information technology, above all with respect to solving the problems of the so-called human-machine interfaces. For the working environment the result is that information technology can both develop and offer the means for creating previously impossible production- and human-oriented work contents and forms of organization. On the other hand, it can also be a source of new problems, which must be addressed by means of organizational, competence-based, and technically creative measures.

It is a well-known and general consensus today that looking and acting merely in the direction of technological issues in this technical-scientific progress and economic structural change leads only to suboptimal results. Concepts for the exclusive conversion of a company to

technology ("factory devoid of humans," "paperless office") are today scarcely pursued, since it is well known that their effectiveness is limited. It has turned out that introductory strategies concentrating exclusively on technical measures on the whole retain organizational forms which continue to rely heavily on division of labor and interpret questions of competence solely in the form of service manuals, are not very successful in applying the new technologies and insufficiently utilize the opportunities of the new technologies. Today one seeks comprehensive innovation concepts, whose general design solutions are aimed at including the technical, organizational, competence-related and health aspects in their contexts and in their interactions. Integrated into them are also aspects of occupational safety and environmental protection. Furthermore, in order for economic and service sectors with new information technologies to achieve a breakthrough, only those design solutions are regarded as promising for the future which support and further develop the creativity and motivation of the employees.

The Work and Technology research and development program pursues such design solutions. Innovations are picked up which in equal measure serve the goals of achieving a higher level of production and service and a more human and socially acceptable work layout. Here, giving such design solutions a preventive orientation is an important precondition for successful innovations. That is why the employees' health and competence must be taken into account and safeguarded so far in advance.

For productive utilization of information technology in the workplace an intense dialog between those who use the new technologies and those who develop it is essential. One characteristic of the subsidy measures of the Work and Technology program is therefore to influence the dialog between users and manufacturers of information technology solutions at all levels.

Key words such as "knowledge-based systems, communications networks, distributed systems, multimedia systems" describe new steps in information technology development, particularly from the aspect of business applications. In order to be able to achieve the productivity effects and competitive advantages seen here and expected by professional people, the experience so far, for example with people-oriented software design and with the making of it, will be used in the dialog between the affected and the developers and included in the development processes of the new generation of information technology. Development and testing of suitable methods and processes for acquiring, representing, applying and maintaining knowledge, development and testing of concepts adapted to the work organization for controlling the distribution of knowledge and utilization of knowledge in production and service organizations are needed. Only in this way can the potentials of human expert knowledge be better used and, on the other hand, the experts be more effectively supported by new systems in their activity or in new undertakings.

In order to be able to overcome the bottlenecks which are emerging in the labor markets, considerable subsidy efforts continue to be needed through information-technical solution concepts. New forms of organizing the work and innovation by and in businesses need information technology support, which can no longer be conceived solely as an island solution but must be integrated and networked into a company-wide innovation strategy. Utilizing the know-how of the workforce in organization and application is crucial for this success. This applies also to the observable trend in the economy to concentrate increasingly on information technology with the growing separation of production and service functions and to find new forms of collaboration above the company level. Here it is mainly a matter of developing and testing logistical concepts supported by information technology, which are flexible enough to be able to exist in the complexity of everyday operation and be usable by labor forces with the most varied qualifications, essentially without additional work load.

In the current discussion about new concepts for work and production, questions of group work today occupy a great deal of space. These ideas are often—particularly when based on analyses of the Japanese economy—given a key role in solving questions of long-term competitiveness. Special information technology solutions to support group work, for example in the form of planning islands or commercial-technical teams are still lacking. Information technology can and will contribute to making advanced group work useful for companies and employees and to support business-related answers to concepts involving participation and competence.

In addition, there is also a need for business models for the use of information technology solutions based on new production and service concepts. Concepts for an organizational and information-technical integration of the workshop and the business sectors that precede and follow it, as well as new forms of organizational arrangement of the company-wide order process based on new concepts of technical organization for integration and networking, must be found and tested.

Tendencies toward a change in the existing business structures, for example through the increasing separation of manufacturing and service functions from the production sector, require new forms of cooperation on a level above the companies, founded on information technology support. Examples of this are new logistics concepts, new concepts for the relationship between "producer and supplier" and integration of the traffic carriers. These forms of organization must be designed with the help of information-technical support in such a way that they do not lead to additional burdens on the people active in the system. At the same time they must be flexible enough to follow the rapidly changing forms of everyday business and the requirements of workforces with different qualifications in various economic sectors.

**4.7 Assessment of the Consequences of Technology**

The technical, economic and social change accompanying information technology opened up the questions of the consequences of these technologies even at an early stage. While in the 1970's the concerns of the workplace, taken up in the BMFT's Humanization of Life at Work program, were in the foreground, in the 1980's information technology in its entire breadth became the object of evaluation of the consequences of technology. Out of the extensive discussions about developments and consequences emerged orientations for subsequent research tasks, which in part have remained in effect until today. Thus, the awareness grew that the evaluation of technical developments should take place in a forward-looking and problem-oriented manner, in order early on to obtain suggestions for research support and technology design. This presumes an evaluation of the anticipated technology distribution, since potential consequences are greatly determined by application range. It also became increasingly clear that information technology in the context of its systems and effects needs to be considered on an interdisciplinary level.

Technology consequence assessment (TA) of information technology is an integrated component of the Federal Government's future concept for information technology. It is today carried out by the BMFT in three course of action.

**4.7.1 Research on Technology Consequence Assessment**

Subsidies are provided for research projects and studies in specific subject fields, which have obviously become urgent as a result of the development level of the technology or its effective distribution. These are, for example:

—Environmental and health effects from production and disposal of components and integrated circuits in microelectronics.

In view of the enormous economic and technological importance of microelectronics, as well as the previously mentioned assumption of potential environmental and health hazards from production of microelectronic components, it is appropriate to undertake a preventive technology consequence assessment for the manufacture and disposal of highly integrated circuits, as well as for the equipment produced with them. This consequence assessment investigates production processes, material handling for individual process steps and the effects of replacement materials on production and disposal of components.

—Technology Consequence Assessment of the Field of Artificial Intelligence (AI), Principally of the Expert Systems

Ways are sought for incorporating technology consequence assessment into the development process for AI and information systems. Based on including fundamental changes in the knowledge production process and knowledge processing, design proposals are being put forward for user-friendly and socially acceptable utilization of these technologies. In so doing, the incentives of the Inquiry Commission on Technology Consequence Assessment will also be taken into account.

—Technology Consequence Assessment and Organization Proposals for Information Technology Infrastructures Using the Example of Telecommunications Services and Chip Cards

Using the example of telecommunications services and chip cards, organization proposals are developed for the way in which future forms of telecooperation can be designed while preserving the personal rights and constitutional compatibility of these services.

—Security of Data Networks and Systems

In addition to the problem of data protection and the consequences which arise for the law and legal systems out of new information and communications technologies, issues of security in data networks, as for example in ISDN, were also studied.

Research and evaluation of expert systems, including from the aspect of data protection and data security, was started. A future focal point for technology consequence assessment is the opportunities and risks of networking in information technology. Such studies have been initiated abroad in recent years, for example in the United States, for the purpose of discovering, using expert systems, potential breakins into information technology systems. Going further than this are attempts to study whether and if expert knowledge of attacks can be generally integrated into the knowledge base of AI systems. The growing networking of information technology increases the importance of these studies.

**4.7.2 Interdisciplinary Discussion of Systems Relationships**

In a second course of action interdisciplinary communication concerning important questions on information technology is being initiated in the scientific and social discussion. In technical and scientific associations there have been initial discussions dealing for example with the human image in artificial intelligence, with designing telecommunications systems from the aspect of self-determination in information and with turning information science from a narrow technical-theoretical aspect toward its social-structural implications as well as their social and cultural responsibility.

**4.7.3 Technology Assessment Dialog**

Decisions on technology policy need the broadest possible and most scientifically assured base. Thus, using the framework of expert commissions, technology assessment discussions are held on selected future-oriented disciplines. Mention should here be made of the Expert Commission on

Neurobiology, Neuroinformation Science and Artificial Intelligence, which has dealt with future developments, particularly the synergy effects between neurobiology and neuroinformation science and their potential effects. The Expert Commission on Opportunities and Risks in Computer-Integrated Manufacture dealt with problems of CIM introduction in businesses and on a level above businesses. Shortly, the importance of information technology development for the basic rights will be taken up by an expert commission. Additional forms of dialog are being tested and employed.

#### 4.7.4 Technology Consequence Assessment Within the Framework of Additional Program Initiatives

Flanking these three courses of action, the BMFT is supported by structuring discussions on consequence assessment of information technology based on the application-relevant technology developments, as well as by the establishment of an informational network in the field of information technology for technology assessment.

It is also assured that the tasks of assessing technological consequences will be included within the scope of other program approaches:

—Technology Consequence Assessment and Organization Within the Framework of the Work And Technology Program

The question of organizing working conditions while including modern developments in the field of information technology is the task of the Work and Technology program (see Chapter 4.6). Here the focal point of the support is the development of human-oriented office and administrative jobs in networked systems, human-oriented industrial work with computer-integrated manufacturing processes, as well as future-related continuing education concepts, which enable the employees to deal with information technology in a satisfactory and competent way. These projects are also being carried out under the BMFT's Manufacturing Technology subsidy program.

Questions of the effects of information technology on the private sphere are handled within the framework of the research program called Sociological Technology Research.

Because of the widely varying need for action in, and as a consequence of, the development of information technology, the BMFT will continue to support technology consequence assessment through various courses of action. Here it will be necessary to examine whether it makes sense to focus more strongly on the topic by using emerging application fields, such as can be expected with the rapidly progressing "networking" or the "mediatization of the empirical world." The distribution and implementation of acquired knowledge should be promoted through information measures and by organizing exchanges of experience.

## 5. Cooperation in Europe

### 5.1 Initial Situation

In the global competition, worldwide production of information technology was distributed as follows between 1984 and 1989:

| Region/share in percent | 1984 | 1989 |
|---|---|---|
| Europe | 21 | 22 |
| United States | 48 | 39 |
| Others | 11 | 14 |

Regional distribution of world production of information technology. Source: EIC 1990

The trade balance in the field of information technology shows the strengths and weaknesses of the regions: Only Japan is now in the situation of producing more than it can use itself.

| Region/share in billion dollars | 1984 | 1989 |
|---|---|---|
| Europe | -12.0 | -33.3 |
| United States | +0.9 | -6.5 |
| Japan | +30.7 | +54.7 |
| Others | -19.6 | -14.9 |

Trade Balance for Information Technology. Source: EIC 1990

The funding of R&D cooperations across the borders serves to strengthen the competitiveness of the European information technology industry as well as increase application of information technology in Europe. A more detailed analysis of the competitiveness of the European information technology industry is found in the report of the Commission of the European Communities "The European Electronics and Information Technology Industry: Situation, Opportunities and Risks, Proposals for Action" of April 1991.

International cooperation in R&D in the field of information technology is marked by the EUREKA initiative, the EC programs ESPRIT, RACE and TELEMATICS.

### 5.2 EUREKA Initiative

In contrast to the joint programs of the European Communities (EC) such as ESPRIT, EUREKA is not characterized by cooperation subjects defined and controlled by all partner nations, but by an unbureaucratically regulated framework for independent finding of cooperation partners across national borders. As a result, this opens up a broad search process for profitable collaboration opportunities, which leaves the actual sponsors of the technological development, meaning the industrial enterprises and the research establishments, a maximum of independent initiative.

The companies/research institutions participating in a EUREKA project assume financing of this project with their own contributions or by taking advantage of the

capital market and, if needed, by making use of the public funds available to them for this purpose.

The EUREKA initiative has become a success story half a decade after its founding, primarily for information technology. About half of all the money was spent on information technology cooperations, for the HDTV standardization projects or the JESSI initiative, among others.

**5.3 The Third EC R&D Framework Program 1990-1994**

In supporting the *information technologies* (ESPRIT), the EC Commission expressly stressed the value of continuing the subject concentrations begun in the second framework program. Research and development work is supported in the fields of:

- microelectronics, optoelectronics
- information processing systems and software
- office communication, individual communications
- computer-integrated manufacture (CIM)

For the *communications technologies* (RACE), in addition to further development of the technological basis for broadband communication, primarily the implementation of new broadband services and applications is in the foreground, in order to test the acceptance of technical solutions and to open up new markets.

The *telecommunications science systems* (TELEMATICS) encompass a series of ongoing user programs for information and communications technologies, such as AIM (health system), DRIVE (transportation system), DELTA (remote learning) or the activities to network the European administrations (European Nervous System/ENS).

The EC programs are based on nationally existing known-how and are aimed at the broadest possible, Europe-wide implementation of this basic and technological knowledge through precompetitive research work. The differential in scientific-technical potential among the EC member nations contributes to a strong application orientation in European research policy. Strong national research in the early stages of the EC measures is fertile ground for a successful European research and technology policy.

German partners are involved in about 80 percent of all EC projects in the field of information technology. That is why they have easy access to all the results achieved in each of the programs. These participations yield a 22 percent average return flow of funds of the entire information technology budget.

If this high ratio can be kept up, about DM 1.1 billion from the Third R&D Program for 1990-1994 now in effect for information technology development will go to German partners, meaning an annual average of DM 240 million, with a growing tendency.

In view of this key role of the information and communications technology for the competitiveness of the economy as a whole, as well as the increasing EC funds for R&D projects in this field, the BMFT has produced a 10-point memorandum on research support by the European Community in the field of information and communications technology and presented it to the EC Commission. The memorandum stresses the importance of the European research policy as a supplementary measure to the national research and technology policy. Nevertheless, there are also points of criticism.

Above all, one must work to oppose the increasing fragmentation regarding topics for the EC subsidy programs. An important demand in this memorandum is to orient the European R&D subsidy programs ESPRIT, RACE and TELEMATICS more sharply toward strategic concentrations in the future. This could be achieved in practice by integrating EUREKA initiatives such as JESSI more extensively than before into the community's funding. For the JESSI research program, it means in concrete terms that the Commission should support this program as originally planned with a subsidy ratio of 25 percent instead of the present participation of only 15 percent. Another proposal in the memorandum is aimed at facilitating access to European subsidy programs for small and medium-sized companies, which are frequently shut off from participating by administrative requirements. In the field of R&D before standards have been set, standardization initiatives must not remain limited to Europe but must be oriented toward the global market at an early stage. The example of a European standard for digital VHF broadcast (DAB) presented at the International Broadcasting Fair in Berlin in 1991 makes it clear how important early coordination with competing regions is: The United States offered to take over the European development standard.

The BMFT repeated these ideas in its February 1992 memorandum on European research policy in general, and as key topics and projects for the future European information technology policy it outlined microelectronics/Project JESSI, high-performance computing, and the flat screen.

In the field of software development, preparations for forming a European Software Institute (ESI) have been started chiefly through the engagement of the information technology industry. Based on the strengthening positions of large overseas software suppliers in Europe and the growing importance of software in information and communications technology systems, the BMFT supports these initiatives. It advocates the participation of the EC in subsidizing a European Software Institute, with an amount that should be equivalent to about half of the total spending for the institute.

The BMFT agrees with the Commission of the European Communities on the general strategy that the necessary measures to expand the competitiveness of the information technology industry primarily represent a challenge for the initiative and responsibility of the companies themselves. At the European level, just as on the national level, the governments and the EC Commission need to

have an industrial and technology policy, an educational policy, a trade policy and tax policy in order to assure a favorable environment for the development of the companies. In the decision by the Council of EC Ministers of Industry on 18 November 1991, as well as with the incorporation of an article on European industrial policy in the Maastricht Treaties (Article 130, Industrial Policy), a framework for additional action on industry and technology on the European level has been created.

## 6. Funding

### 6.1 Government Research Funding of Information Technology

Research and development in the field of information technology is supported in the FRG by the Federal Government, the laender and the European Communities. In 1992 about DM 1.6 billion in government funding was spent. This is a share of about 14 percent of the national spending for research and development in the field of information technology in the FRG. The total spending by the BMFT in the field of information technology amounted to DM 1.11 billion in 1992, of which DM 673 million were used for project funding and DM 437 million for institutional support of government research establishments.

The BMFT's funding on behalf of information technology (including production engineering) has grown from DM 635 in 1984 to DM 1.11 billion in 1992. About 60 percent of these funds are used to subsidize research projects.

In all, promotion of economic development does not dominate the BMFT's project support. The importance of academic institutions and research establishments outside universities has increased, so that public research and the economic sector each receive half of the funds used by the BMFT to support projects. This corresponds with the policy described in Chapter 1, to create a strong public research infrastructure for the FRG and to support the transfer of research results to industrial application by way of project collaboration by science and the economy.

**Fig. 24: BMFT Funding of Information Technology Including Production Engineering 1984-1992. (Project support and institutional support by the BMFT to GFE [large research institutions], BLE [Blue List institutions], FhG [Fraunhofer Society] and MPG [Max-Planck Society])**

| (in million DM) | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 pr[illegible] |
|---|---|---|---|---|---|---|---|---|---|
| Project funding and instit. funding of GFE and BLE | 583 | 624 | 787 | 834 | 779 | 702 | 732 | 832 | 1,001 |
| Instit. funding of FhG and MPG | 52 | 55 | 57 | 63 | 65 | 66 | 67 | 82 | 109 |
| Total | 635 | 679 | 844 | 897 | 844 | 768 | 799 | 914 | 1,110 |

By way of project funding and indirect-specific subsidy measures, the BMFT also supports particularly the strengthening of R&D in small and medium-sized enterprises, which preferably work with the application of microelectronic components or with micromechanical systems. Small and medium-sized enterprises thus reached a share of 43 percent of the total BMFT funding of the economic sector for 1991. The German information and communications engineering industry also has a share of more than 70 percent of the R&D projects in information technology funded by the European Communities in the FRG, of which about 20 percent of the funding goes to small and medium-sized companies (see Chapter 6.2).

### 6.2 Additional Development of Information Technology Funding

**BMFT Subsidies**

The BMFT's subsidies for research and development in the field of information technology has grown over the years 1991 and 1992 to more than DM 300 million. This is justified by a clear increase in project support and the incorporation of the new laender into the research landscape, as well as by new research institutes having been founded over there. The publicly supported research infrastructure has thus experienced competent growth; in particular, mention should here be made of the new location for the Society for Mathematics and Data Processing in Berlin-Adlershof and the Institute for Crystal Growth in Berlin, the Institute for Semiconductor Physics in Frankfurt/Oder, the Ferdinand Braun Institute for Ultrahigh Frequency Technology in Berlin and the Paul Drude Institute for Solid State Electronics in Berlin.

This year the support for information technology will reach a share of 12 percent of the BMFT's budget. This high level is to be maintained in subsequent years as well (data in million DM).

| | 1993 | 1994 | 1995 | 1996 |
|---|---|---|---|---|
| Instit. support | 464 | 459 | 467 | 477 |
| Project support | 671 | 670 | 670 | 670 |
| Total BMFT support | 1,135 | 1,129 | 1,137 | 1,147 |
| (Figures according to cabinet decision on 1 July 1992) | | | | |

This includes institutional support for the relevant large research facilities and institutes on the Blue List, as well as the share of institutional BMFT support in the field of information technology for Fraunhofer Society and the Max Planck Society establishments (see Chapter 7.1).

In the supplementary process of supporting research in conjunction with EC subsidy measures and the TELEKOM's research activities, the BMFT's financial planning will continue to place its main emphasis on funding basic research as well as safeguarding and expanding a strong research infrastructure, including the conversion of research results into industrial application. By means of dividing the labor so that it is also conceptually balanced, one will ensure that the increasing project funds from the EC and the distribution of development contracts by TELEKOM are optimally utilized by a stable research landscape in the FRG and connected to focal points in basic research. In addition to the function of immediate financial support, it will be important for the BMFT to monitor this supplementary process, which is a continuation of the conceptual guidelines for overall R&D funding in the field of information technology.

**The EC Subsidies**

In the Th. d Research Framework Program for 1990-1994 of the European Communities, information technology is the definite key sector with DM 4.4 billion (39 percent of the total budget of 5,7 billion ECU = DM 11.4 billion). Information technology is supported along three lines of research:

- Information technologies (ESPRIT); 1990-1994 = DM 2.74 billion
- Communications technologies (RACE); 1990-1994 = DM 978 million
- Telecommunications systems (AIM, DRIVE, DELTA, etc.); 1990-1994 = DM 760 million

Each of these is a continuation of research work from the EC's Second and First R&D Framework Programs.

In order to further develop the R&D framework program, the draft of the financial preview for 1993-1997 in the Delors-II package foresees an increase in the research budget share (commitment appropriations) from about 3.5 percent in 1992 to 5-6 percent in 1997. In the Commission's communication to the European Council and the European Parliament called "Research After Maastricht: Balance and Strategy" of 9 April 1992, the following plan figures for the R&D budget are mentioned (in million ECU, cost base 1992):

| | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 |
|---|---|---|---|---|---|---|
| R&D budget | 2,448 | 2,730 | 3,040 | 3,380 | 3,770 | 4,200 |

This financial planning also includes an increase in the Third R&D Framework Program for 1993/94 supplied in the resolution for this framework program as compensation for the 2 billion ECU cut at the time of the Commission's proposal.

The Commission presented its proposal for the 1.6 billion ECU increase on 15 July 1992 (an additional 625 million ECU are suggested for information technology). The organs of the European Commission have not yet made a decision about the financial planning and this increase. Also, no information is available as yet regarding priority subjects and the breakdown of the funds.

The BMFT greets and advocates both the increase in the Third R&D Framework Program and the increase in funding for R&D in general. But the higher funding should be taken from shifting around rather than increasing the total budget of the EC. The Federal Government, at least, assumes that information technology in the EC's future research funding will have the same importance as today. In Fig. 25 the same assumptions are made for 1993 as for 1992 (meaning the information technology share of the framework program: 39 percent; return flow of information technology funds to the FRG: 22 percent).

**Fig. 25: Funding for Information Technology 1990-1993 (in million DM)**

| | actual 1990 | actual 1991 | proj. 1992 | proj. 1993 |
|---|---|---|---|---|
| EC return flow | 168 | 222 | 278 | 468 |
| DFG, laender | 150 | 170 | 231 | 240 |
| BMFT | 799 | 914 | 1,110 | 1,135 |
| (institutional support) | (300) | (316) | (437) | (464) |
| (project support) | (499) | (598) | (673) | (671) |
| Total | 1,117 | 1,306 | 1,619 | 1,843 |

(BMFT figures for 1993 according to cabinet decision of 1 July 1992)

**DBP TELEKOM Research**

In Chapter 4.5 it was shown that after the postal reform TELEKOM, with its own research and granting of R&D contracts, is to form a bridge between public research subsidies on the one hand and industrial research on the other. Government research will thus be able to concentrate more heavily than before on researching and offering basic technologies such as optoelectronics, photonics or broadband technology, while TELEKOM safeguards application-oriented implementation in the entrepreneurial interest.

DBP TELEKOM will considerably increase its R&D spending in the field of information technology with a focal point on telecommunications from DM 511 million, by way of DM 732 million for 1992, to approximately DM 910 million in 1993. Its R&D spending would then amount to 1.7 percent of its planned turnover.

**7. Supplements**

**7.1 Research Establishments in the Field of Information Technology (as represented by the institutes themselves)**

**7.1.1 Max Planck Society**

Within the Max Planck Society a large number of institutes are occupied with tasks and problems which are covered under the BMFT's information technology subsidy concept:

1. The newly founded Max Planck Institute for Information Technology should be especially pointed out, which began its work in December 1990 and at this time has two departments. In the department of Data Structure and Algorithms, which is headed by Professor Mehlhorn, efficient algorithms and data structures for sequential and parallel computers are being developed. The principal application fields for these algorithms are computer-supported design and efficient data holding in computer systems.

In the department of Logic in Programming, which is headed by Professor Ganzinger, the logical principles of programming and program development are the object of studies. The experimental work correspondingly deals with conception and realization of interpreters and program development systems.

The Statistical Yearbook of the Max Planck Society shows an annual expenditure for the research field of information science in the amount of approximately DM 12 million.

In this context, reference should be made to the founding of the Fault-Tolerant Computing working group at the University of Potsdam under the leadership of Professor Goessel, which began its work on 1 January 1992 and is administered by the Max Planck Institute for Information Science. The working group investigates the task of achieving correct results under the conditions of certain hardware and software errors. In concrete terms, it works with systems design of self-checking and self-testing circuits. The annual research expenditure for this group is at present about DM 1 million.

2. Other than that, the following Max Planck Society institutes work in subfields which touch on the funding concept:

2.1 The Max Planck Institute for Solid State Research is active in, among others, the field of microelectronics based on semiconductors and molecular electronics. The annual research spending in this field amounts to about DM 8 million. In this context the newly founded Theory of Dimension-Reduced Semiconductors working group at Humboldt University in Berlin should be mentioned, which is administered by the Stuttgart Institute.

2.2. The Max Planck Institute for Metal Research is active in the field of high-temperature superconducting, for example. The annual research funding for this is 10 percent of the institute budget or DM 2 million.

2.3 The Max Planck Institute for Quantum Optics also works in the field of photonics. The annual research spending for this is about DM 1.7 million.

2.4 The Max Planck Institute for Nuclear Physics is active in the field of microelectronics based on semiconductors (ion implantation), among others. The annual research spending for this is DM 1.75 million.

2.5 The Max Planck Institute for Radio Astronomy also works in the field of the new basic technologies in the sense of the subsidy concept, insofar as it relates to diode development based on SIS [not further identified] technology. The annual research budget is about DM 0.5 million.

2.6 The Max Planck Institute for Brain Research is active in, among others, the fields of Artificial Intelligence, Neuroinformation Science and Bioinformation Science. The annual research spending is approximately DM 2.5 million.

2.7 The Max Planck Institute for Psycholinguistics is active in the field of language translation, among others. The annual research budget is about DM 0.5 million.

3. Total spending by the Max Planck Society from the aspects of sections 1 and 2 is about DM 30 to 35 million annually. The list does not include the Max Planck Institute for Plasma Physics in Garching. At that institute the working group of Professor Hertweck also works in the field of Scientific Supercomputing.

### 7.1.2 Major Research Establishments

**Society for Mathematics and Data Processing (GMD)**

With its future paper "Achievements for Today and Goals for Tomorrow," the Society for Mathematics and Data Processing mbh (GMD) takes on the following research policy challenges and subject concentrations:

- **Parallel Computing**
- creation of an attractive internationally recognized research and Production Center for Parallel Computing
- establishment of a basic technology which permits systematic and comfortable utilization of parallel computing technology
- support of an integration of mathematics and information science
- application-related interdisciplinary research and development in the field of algorithms, methods, models and systems, including the corresponding software development, particularly in the fields of climate and environmental research, flow mechanics, molecular biology and bioinformation science.

- **Intelligent Multimedia Systems**
- man-machine interface
- systems with assistant features
- artificial intelligence, semantic analyses of multimedia contents, use of expert systems in knowledge banks
- interactive simulation of complex dynamic systems
- visual exploration
- multimedia author and retrieval systems

- **Cooperation and Communications Systems**
- Concept formation for an open and secure, need-oriented systems architecture
- Methods and tools for creating reliable cooperation support systems
- Modelling of cooperation processes
- Technical availability of organizational knowledge in standardized directory systems
- Making complex information contexts available in distributed data bases
- Multimedia document exchange
- Multimedia high-speed communication

- **Design Methods**
- Integrated hardware and software design technology
- Architecture and systems concepts
- Innovative languages
- Software technology
- Specification of distributed applications
- Offering a "clearing house" for systems engineering based on object-oriented design components

Structurally, the GMD has eight institutes divided between three locations. In the future, the Berlin location will be concentrated in Berlin-Adlershof. By means of outstanding integration or pilot projects, the GMD's research work is to become evident to the outside through visible results. Thus, for every research concentration at least one integration project on a level above the institute, such as POLIKOM, is being established. The "large-scale" focusing on selected integration projects sought with the demonstration projects will be picked up on a "small scale" in pilot projects (1-2 per institute).

The financial planning for the GDM will in future years be oriented around the following key data for BMFT funding:

| 1992 | 1993 | 1994 | 1995 | 1996 |
|---|---|---|---|---|
| 112.2 | 117.1 | 117.3 | 117.4 | 120.9 |

**Juelich Research Center GmbH (KFA)**

Information technology represents one of five research concentrations at KFA. This includes new basic technologies under the basic research in information technology program, in information science as well as measurement technology and digital electronics.

At the center of the Basic Research in Information Technology program stands the Institute for Layer and Ion Technology (ISI) with its two sub-institutes for Semiconductor Electronics and Technology and Superconducting Electronics and Technology. The projects undertake medium and long-term research in the field of pre-industrial development and application for the following concentrations and goals:

- Epitaxy of Si/Ge, Si/silicide structures and III-V semiconductor layer systems
- Structuring of semiconductor layer systems
- Superconductor-layer systems for potential applications in quantum interferometers, high-frequency components, vortex registers, etc.
- Superconductor-semiconductor hybrid structures
- Layer materials for magnetic and magnetic-optical information storage
- New types of components and quantum structures
- Crystal growth for compound semiconductors

The work on Scientific Computing was administered by the Central Institute for Applied Mathematics. It derives

its motivation and strength primarily from the exciting field of highly advanced scientific and technical infrastructure and technically far-ranging research, which creates new research tools out of information technology and computing.

Among them are principally:

- Mathematical methods and algorithms for new computer structures, parallel algorithms,
- Programming methods and tools
- Operating software and performance analyses
- Computer networks and distributed systems
- Supercomputer applications, simulation and visualization.

From this work there are many close connections with other institutions at home and abroad. Among them are also cooperations with companies manufacturing supercomputers.

Included in the additional activities of the KFA in the field of information technology are research and development projects on Measurement Technology and Digital Technology. They incorporate the subjects of:

- Guidance system technology, as well as measurement, control and automatic engineering,
- Real-time systems,
- Hardware and software for high-resolution image processing,
- Sensors, particularly for medical applications.

In this work as well there are numerous cooperative ties to research institutes and industrial enterprises.

The use of personnel for R&D projects in the field of information technology at KFA right now amounts to about 250 man years. In the following years a slight personnel increase is planned in this sector. In all, KFA spends about DM 80 million annually on information technology projects.

**Karlsruhe Nuclear Research Center (KfK)**

In addition to environmental and energy research, the KfK's research program includes microsystem technology as a third priority area for the work. In the pre-industrial development area and in close cooperation with academic institutions, other research institutions and industry, it is thus making a contribution to the development of this promising technology. Other work deals with superconductivity in electronics and precision measurement technology using both conventional and high-temperature superconductors.

Microsystem technology is aimed at the development of individual microcomponents and their integration into complex systems, using information processing in order to offer opportunities for the solution of as many problems as possible in all areas of technology with the greatest reliability. The KfK's work is directed toward optimization of production methods for microstructures for application in industry, toward offering reliable miniaturized sensors and actors for a broad spectrum of applications, the development of new signal processing concepts as well as making design environments available for developing application-specific circuits and entire microsystems. The LIGA [lithography, electroforming, casting] process developed at KfK plays an important role here. By means of close cooperation with industry it is assured that the work is always oriented toward foreseeable industrial applications.

The Microsystem Technology work program is divided into the seven fields of:

- Microstructuring
- Materials development for microsystem technology
- Sensor and actor development
- Structuring and connection technology
- Systems technologies
- Applications
- Foundations for micro-/nanotechnology.

Although the work in microsystem technology is undertaken at institutes for individual subjects, in nearly all cases interdisciplinary cooperation on a level above the institute is what achieves success. In addition to the Institute for Microstructure Technology (IMT), the following institutes are integrated into this priority work category: Institute for Radiochemistry (IRCh) with the field of microanalysis, Institute for Applied Information Science (IAI) with the field of software development and systems integration, Institute for Materials Research (IMF) with the areas of Microtribology as well as materials development and process technology, Institute for Nuclear Solid State Physics (INFP) with the fields of surface technology and nanotechnology and the Main Department of Engineering Technology (HIT), among others, with the field of handling technology, for example for minimally invasive surgical procedures.

**7.1.3 Fraunhofer Society**

The FhG conducts research and development in the field of information technology including microtechnology at 14 institutes. With about 1,350 regular employees and a budget of not quite DM 250 million for 1992, the FhG covers the entire breadth of the BMFT's Information Technology Subsidy Concept with varying intensity. The financing for this spending comes from Federal Government institutional support in the amount of approximately DM 93 million and from the laender, from third-party funding for project support, including EC projects, as well as from business profits. The selection of R&D concentrations follows the development of the German microelectronic and information technology industry. Accordingly, the capacity of microsystem technology, neuroinformation technology, telecommunications research and software engineering will continue to grow, while X-ray lithography is being cut back.

The senate of the FhG has decided to reestablish the Institute for Silicon Technology (IsiT) in Itzehoe. The cost of construction and initial equipment are borne in equal parts by the BMFT and the land of Schleswig-Holstein.

The focal points of the work program will be the development of technologies for highly integrated, application-specific circuits (ASICs) and microsystem technology based on silicon. The work includes contributions to the manufacturing technology. It will take place in early and close contact with industry. The work program will begin in early 1993 at the Institute for Microstructure Technology (IMT) in Berlin. The IMT will then be renamed the ISiT-Berlin and, after completion of the buildings in Itzehoe, move there.

The intent is also to create a Fraunhofer establishment for Reliability and Microintegration in Berlin beginning in 1993. The work program focuses on a very important problem in microsystems.

In joint work with small and medium-sized enterprises, product-oriented R&D work with a time frame of up to five years for improving the performance of the economic sector is in the foreground. Examples are the development of application-specific customer circuits, additional development of semiconductor production equipment, sensor and actor development based on silicon, automation of production facilities, making quality assurance more flexible, developing progressive information and communications systems, simulation technology, further development of image and signal processing, development of microsystems and their reliability for various applications (such as in medical technology).

In agreement with the research and technology policy of the Federal Government, individual laender as well as the Commission of the European Communities, the FhG is required to participate in the pre-industrial application field in developing basic future technologies. The FhG is able to transfer the results in the form of interdisciplinary system solutions to small and medium-sized enterprises and thus make a contribution to the competitiveness of the German economy. Since the development risks are high, and research in the economic sector at home and abroad is government-supported, the dominant activity at FhG is cooperation with the economy on joint projects publicly funded by the BMFT and the EC Commission. Examples of the development of a few key technologies and important fields of activity for the FhG in information technology are:

- The development of process technology and of integrated circuits in the Ghz range and for optical applications based on compound semiconductors (III-V ELEKTRONIK cooperative project).
- Further development of methods for data reduction of audio signals and their application in telecommunications, audio signal transmission and storage systems (EUREKA project DIGITAL AUDIO BROADCASTING, DAB).
- The development of process technology and of semiconductor production equipment for the manufacture of super-integrated silicon components with structures in the submicron range.
- Working out information technologies to support motor vehicle transportation (EUREKA project PROMETHEUS).
- The additional development of automatic image and image sequence evaluation as a source of information in monitoring and controlling production facilities, in quality assurance and in monitoring industrial and natural environments.
- Participation in ESPRIT and RACE projects, as well as in other joint BMFT projects.
- Generation of studies on technology consequence assessment.

The examples listed illustrate the FhG's ability to have a trustful working relationship with the economy and the public sector. Partners in the economic sector to a major extent represent industrially leading enterprises.

#### 7.1.4 Blue List Institutes

With the incorporation of the new laender into the research landscape and the founding of new Blue List research institutes over there, publicly funded research has been reinforced in the field of information technology, above all. In addition to the Heinrich Hertz Institute for Communications Technology in Berlin, as the only Blue List institute so far in the field of information and communications technology, the newly founded establishments of the Institute for Crystal Growth in Berlin, the Institute for Semiconductor Physics in Frankfurt/Oder, the Ferdinand Braun Institute for Ultrahigh Frequency Technology in Berlin and the Paul Drude Institute for Solid State Electronics in Berlin represent a highly competent addition to the research infrastructure in information technology.

1. The Heinrich Hertz Institute for Communications Technology Berlin GmbH (HHI) conducts application-oriented basic research in information and communications technology with concentrations in

- photonics (optical signal processing),
- broadband networks,
- integrated optics,
- electronic imaging techniques.

An overview of BMFT funding as of July 1992 (million DM):

| 1992 | 1993 | 1994 | 1995 | 1996 |
|---|---|---|---|---|
| 15.3 | 15.8 | 16.6 | 17.4 | 18.3 |

2. The Ferdinand Braun Institute for Ultrahigh Frequency Technology (FBH) in the Berlin Research Group e.V. works with concentrations in ultrahigh frequency technology for mobile and stationary radio networks, optoelectronics with respect to the integration of photonic and microwave-electronic components, and complex layer structures for very high frequency technology and photonics by means of gas phase epitaxy (MoCVD).

An overview of BMFT funding as of July 1992 (million DM):

| 1992 | 1993 | 1994 | 1995 | 1996 |
|---|---|---|---|---|
| 7.8 | 8.4 | 8.9 | 9.1 | 9.4 |

3. The Paul Drude Institute for Solid State Electronics (PDI) in the Berlin Research Group e.V. conducts basic research in the physics of III-V compound semiconductors. Among them are the studies production of low-dimensional III-V semiconductor structures, charge transportation in microstructures, characterization of microstructures by optical means, and quantum effects in structures with low dimension.

An overview of BMFT funding as of July 1992 (million DM):

| 1992 | 1993 | 1994 | 1995 | 1996 |
|---|---|---|---|---|
| 4.2 | 5.5 | 5.4 | 5.5 | 5.6 |

4. The Institute for Semiconductor Physics Frankfurt/Oder GmbH (IHP) concentrates on application-oriented basic research in the fields of silicon-germanium (Si/Ge) semiconductor physics, SiGe technology and its integration into the traditional silicon technology, nanostructure technology, and microelectronic function elements.

An overview of BMFT funding as of July 1992 (million DM):

| 1992 | 1993 | 1994 | 1995 | 1996 |
|---|---|---|---|---|
| 10.0 | 11.7 | 13.5 | 14.9 | 15.3 |

5. The Institute for Crystal Growth (IKZ) in the Berlin Research Group e.V. is active as a service facility in the fields of growing and defining semiconductors and other crystalline materials, methods to produce these materials, special methods for separating layers based on silicon and other semiconductor materials.

An overview of BMFT funding as of July 1992 (million DM):

| 1992 | 1993 | 1994 | 1995 | 1996 |
|---|---|---|---|---|
| 4.5 | 5.2 | 5.6 | 4.7 | 4.5 |

### 7.2 Information for Applicants, Application Procedures

The subsidy concept for research and development in information technology in question provides a complete overview over the BMFT's funding activities in this field. It is planned that individual focal points in the program should be specified over the term of the program by awarding contracts and detailed subsidy concepts. In addition, reports will be submitted at regular intervals on the research results achieved, so that through this information the remaining research shortcomings can be put into concrete form.

The Federal Ministry for Research and Technology is supported by the following project sponsors in carrying out the subsidy concept for information technology:

a)German Aerospace Research Institute (DLR)

-Project sponsor Information Technology

-* Linder Hoehe 90, 5000 Cologne

-Tel.: 0 22 03/6 01 28 40

-* Rudower Chaussee 5, 0-1199 Berlin-Adlershof

-Radio telephone: 0161 - 6 20 86 18, 0161 - 2 20 56 57

-Tel: 030/677 5091, 030/677 4379

-Project sponsor Work and Technology

-Suedstrasse 125, 5300 Bonn 2 Tel: 02 28/3 82 10

b)VDI/VDE Technologiezentrum Informationstechnik GmbH

-Project sponsor Microsystem Technology

-Budapester Str. 40, W-1000 Berlin 30 Tel: 030/2 64 89-0

c)JESSI Office

-Elektrastr. 6 a, 8000 Munich 81 Tel: 089/9 28 08 20

The Physical and Chemical Technologies program is supported by the project sponsor VDI-Technologiezentrum Physikalische Technologien Postfach 11 39, 4000 Duesseldorf Tel: 0211/ 6 21 40. The Production Technology and Quality Assurance programs by Project sponsor Production Technology and Quality Assurance Kernforschungszentrum Karlsruhe GmbH Postfach 36 40, 7500 Karlsruhe 1 Tel: 072 47/82-0. Project sponsor activities are focused on professional and administrative consultation for the applicant, preparation of subsidy decisions, and project monitoring and performance review.

Information and references to the EC programs can be obtained from Project Sponsor Information Technology in Cologne. Applications for funding of a research and development project under the program in question should be directed to the projects sponsors listed above. It is recommended before formal application to put the research idea into a project outline and to discuss it with the project sponsor responsible for the application.

An important precondition for support is the technical competence and the economic soundness of the applicant.

BMFT projects can be undertaken in the form of so-called joint projects. This means that there must be willingness to cooperate in a consortium.

The enterprises' own interest in the results of the research should manifest itself in an appropriate share of the funding: As a rule the subsidy rate for projects in industrial basic research is up to 50 percent for the benefit of commercial business enterprises.

When it is likely that support will be granted, the project sponsor will send the necessary application forms and guidelines, so that the funding application can be formulated and submitted.

Information about the individual steps for the applicant is shown in the sequence of procedures. Further details can be obtained from the concrete subsidy programs on the key concentrations of this concept as well as from the annually published RESEARCH AND TECHNOLOGY GUIDE.

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